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THE GHANA JOURNAL OF SCIENCE is a periodical devoted to the advancement of scientific knowledge among the general public as well as scientific specialists. It is open to all articles of a scientific and technological nature from Ghana and elsewhere, and the topics need not necessarily be related to West Africa. The Journal is published by the Ghana Science Association with generous financial aid by the Government of Ghana through the National Research Council of Ghana.

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Instructions to Contributors.—Manuscripts may be written in English or French, and should be in double-spaced typescript. Scientific names of plants and animals should be underlined. Each article should be accompanied by a summary, and the whole manuscript should not exceed 10,000 words in length.

Text-figures are accepted as line-drawings accompanied by legends. Labelling on text-figures and graphs should be indicated lightly in pencil in its correct position. Prints or negatives of very good quality are accepted for half-tone plates.

Literature Cited.—A list of the literature cited is to be provided in alphabetical order of the names of the authors. Abbreviations for names of journals should be as in the World List of Scientific Periodicals, and the volume number of the journal should be underlined. Examples of the final form of the reference are:

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Membership of the Ghana Science Association is open to all who will further scientific research and its application, or foster the understanding and teaching of science in Ghana. An annual subscription of £G2 2s. is payable in advance to the Treasurer, Dr. M. J. Baines, University of Ghana.

DEDICATION

FOR HIS KEEN INTEREST IN THE DEVELOPMENT OF SCIENCE AND TECHNOLOGY IN GHANA, THIS FIRST VOLUME OF THE GHANA JOURNAL OF SCIENCE IS PUBLISHED IN HONOUR OF THE 52nd BIRTHDAY OF OSAGYEFO DR. KWAME NKRUMAH, PRESIDENT OF THE REPUBLIC OF GHANA

EDITORIAL

As the Hon. Kofi Baako indicated in his opening address at the First Conference of the Ghana Science Association, the establishment of a new Scientific Journal by the Association is a challenge to all scientists in Ghana to double their efforts in order to obtain suitable material to feed the journal. Our venture in publishing this journal is but a humble beginning, and in this volume we have had to start from scratch in some cases with material that may even not sound strictly scientific but which, we believe, will provide the background for a proper understanding of the more convincing facts when these come to light in the near future.

We are particularly lucky to be honoured by a visit of the International Atomic Energy Mission during the time of our first Conference in Ghana and to be able to join in an illuminating symposium. It is therefore fitting that we have their contributions in this volume.

The *Ghana Journal of Science* is out to help all who seek to know the working of science in the modern world.

The Committee of the Ghana Science Association wish to express their sincere thanks to the National Research Council for providing the necessary financial arrangements to make the institution of this Journal possible.

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OPENING ADDRESS OF THE FIRST CONFERENCE

OF THE

GHANA SCIENCE ASSOCIATION

AT LEGON, ON 31ST MARCH, 1961

by HON. KOFI BAAKO, M.P., *Minister Responsible for Research*

Mr. Chairman, Ladies and Gentlemen—I would like to add " Fellow Scientists ",

Unfortunately my knowledge about Science is such that if I claimed to be a scientist I could be successfully prosecuted in the Court of Law for false pretences!

However, as the Minister responsible to the President for the National Research Council, I can claim to have acquired a reasonable measure of interest in Science and Scientific and Technological research in so far as they relate to the social and economic development of Ghana, Africa and the world in general—and it is for this reason that I am happy to deliver the " opening address "—deputising for the Osagyefo who himself is the Founder and Chairman of the National Research Council and the Academy of Science and Learning.

The National Research Council, as its name implies, has as its prime objective the Co-ordination of Scientific Researches in such fields as are considered necessary for the social and economic development of Ghana and Africa. In this connection the Council's immediate interests lie in such fields as Medical Research with special bias for tropical medicine and endemic diseases; Building Research, in relation to national housing policies and programmes, design, and construction techniques; Road Construction Research with the view to finding the most suitable local materials for the building of our roads at reasonably low costs.

The Council also has as its aim the encouragement and conduction of researches into possible uses of our natural resources—both mineral and vegetational—in order to ensure a higher standard of living through their use. One of the most important Schemes of the National Research Council is a Scheme to conduct research into our indigenous herbs, and to this end approval has been given for post-graduate research grants to suitably qualified Africans to work under Dr. J. A. K. Quartey of the Department of Chemistry of our University College on native herbs, medicine and alkaloids with a view to obtaining the M.Sc. or Ph.D. degrees. You may be happy also to learn of the plans of the Osagyefo's Government to establish in Ghana a Scientific and Medical Research Institute which will have as one of its main units the Institute of Tropical medicine and endemic diseases with which the Liverpool Institute of Tropical Medicine is closely associated.

It is the aim of the Osagyefo and his Government that the Institute, though a Ghanaian project, will have the primary objective of being at the service of all Africa and mankind. It is the Nkrumaist view that Science must not have racial creed, colour or ideological barriers and for this reason the National Research Council aims at achieving its objectives through inter-territorial and international co-operation and collaboration. I am therefore naturally happy to welcome you all here at this conference and to deliver the opening address.

The Osagyefo, whose interest in scientific and technological development for peaceful purposes is so well known, has been unable to attend the opening session of this Conference to deliver the opening address but he has asked me to convey to you his personal good wishes and his Government's support for all your efforts. As a socialist, Dr. Nkrumah holds the view that the development of science should aim at raising the hopes of the world for peace, international co-operation and for man's welfare and happiness.

The President has always stated that Africa has vested interest in Peace. Speaking at the Conference of Independent African States in April, 1958, Dr. Nkrumah *inter alia* said,

> " The goals which we have set before us require a world of order and security in which we can live and work in tranquillity towards their realisation. That is why we have a vested interest in World Peace. Our foreign policies must therefore be such as to contribute towards the realisation of that fundamental objective. As a free and independent nation we must also endeavour to follow the policy of positive non-alignment so as to enable us at any time to adopt measures which will best suit our national interest and promote the cause of peace. It is only by avoiding entanglement in quarrels of the Great Powers that we shall be able to assert our African Personality on the side of peace in conformity with the Charter of the United Nations."

Mr. Chairman, it is clear from this quotation that in Ghana's view, Science and Technology are useful and necessary only to the extent to which they promote peace and development in the world.

I know you have met here for peaceful reasons and may I hope that you will find time to consider inventing a machine or compounding a cure to normalise and correct the frame of mind of those who still think that *Apartheid* has a place in the world. In my view apartheid is a disease for which we must find a cure.

At the same Conference the Osagyefo had this also to say:

> " Addressing ourselves to the cultural aspects of our relationship, we must also examine ways and means to broaden and strengthen our association with one another through such means as the exchange of students and the visits of cultural, scientific and technical missions, both governmental and non-governmental, and the establishment of libraries specialising in various aspects of African history and culture which may become centres of research. There are no limits to which we on this African Continent can enrich our knowledge of our past civilisations and cultural heritage through our co-operative efforts and the pooling of our scientific and technical resources."

May I, Mr. Chairman, as a layman make some general observations on science and its place in our society. In this day and age, science and technology have become the key to progress. The world around us is being created by progress of science. Man to-day knows more about the world than ever before and is continually and increasingly bending the forces of nature to serve his needs. We have witnessed fantastic and breathtaking achievements in space probes and there is a feeling of expectancy and excitement about the first manned flight into space in the immediate future. We are seeing in this century the realisation of the hopes of men of the 17th century like Descartes, who declared that through science we could " become the masters and possessors of Nature." It is now apparent that man is about to reach a state in which he can control his material environment through the conscious use of science. He can secure himself against want, abolish tedious toil and, by rapid stages, reduce misery and disease.

Millions of people are near starvation; millions of people can hardly afford the most basic necessities of life and we in Africa know only too well these harsh facts. The effects of centuries of exploitation, degradation and humiliation are still with us. Politically, we are successfully liberating our continent from foreign domination and our next task is to free it from economic and financial control from outside as well as from technological domination. Independence and freedom are only a means to an end. We must develop our resources so as to give to our people decent life, a longer span of life and fruitful and useful life.

We have to tackle the past immobilities and direct our energies and resources towards the creation of a happy and contented society. Our development policies therefore must be bold and imaginative; they must be radical and purposeful. But I know that if these policies are to have any long term meaning and effect they must be spelled out in terms of scientific and technological trends. As an Nkrumaist, I believe that where all the major means of production and distribution are under the control of the state—where there is neither pernicious monopoly nor unnecessary competition the state can make a deliberate and conscious drive to develop

and use science to the fullest, mainly by creating active centres of research with the object of the scientists securing the most fruitful growth of science and the fullest utilization of natural and human resources for the welfare of the people.

We in Africa have started late in modern development and advancement and for this reason, we have to make shrewd use of science and technology. We have to cram centuries of progress into a decade. This should be possible if we make effective use of the cumulative knowledge at our disposal and learn from the experiences of others, avoiding their mistakes and profiting from their successes. But we should not be receivers only. We should make positive contribution to knowledge and I am convinced that Africans will in time make this contribution.

We are to-day witnessing a new kind of revolution in the world in which planned scientific research is taking the place of individual mechanical ingenuity. Scientific research must be planned instead of being left to the chance of economic forces. In this regard I cite the examples of Soviet Union and of the United States of America which are consciously planning their scientific researches and their application. From what we know and see this practice of conscious planning has produced commendable results and it is heartening to note that it is becoming the general practice in India, China and Europe. It has become clear that the application of science has to be related to human needs and that deliberate and planned scientific efforts should be made to find the means of satisfying these human needs. Governmental science as opposed to private or industrial science is what as an Nkrumaist I wish to see in this country. By governmental science I mean science financed and directed by the state for great constructive and Nature-transforming projects for the welfare of the people.

Science can be a liberating force both in its indirect effects through transforming industry and directly by widening all men's minds and giving them a greater possibility of realising their capacities. In a country like ours, scientific studies, research and their application to problems should serve as material revolutionary force to change our society and also as a lever for the over-throw of past, illusory conceptions of nature based on ignorance and their replacement by fresh, true and more adequate ideas—the liberation of the minds of some of our people from superstition, taboos and unnecessary fear. The Osagyefo's Party and Government attach the greatest importance to the teaching and study of science in this country. Our Primary schools, Secondary and Technical schools are all now placing more emphasis on the teaching and the study of science and the curricula of our schools and colleges are being planned to give more scope to the teaching of science. In our higher institutions Osagyefo himself has stressed the need for scientific research.

I am particularly happy, therefore, to see this conference of Ghana Science Association meeting here to-day. I understand, the theme of your conference is " Science and the Development of Ghana ". This is as it should be. For I believe that our scholars should turn their attention to the problems of the moment and help in finding solutions to them. I believe that academic knowledge gained in our highest institutions should be applied to serve the needs of our people. In the past, this academic knowledge has been too esoteric, but a country like Ghana must expect that those of her sons and daughters who have been fortunate enough to acquire knowledge, or skills should use their talents in the service of the nation and for the benefit of all the people.

The establishment of an annual conference of all scientists in Ghana is a challenge to the productivity of the scientists, for more work will have to be done to provide the material for such conference. I sincerely hope that the works of value which will be read at this conference will not only be recorded for posterity to refer to and improve upon, but will also form a useful basis for discussion and great consequences. I wish to assure you that the Government through the National Research Council would support any move by your Association to publish a *Ghana Journal of Science*. I hope you will seek to associate with similar organisations all over Africa so that the benefit of your findings and of theirs might be exchanged for the general benefit of the people of Africa as a whole and mankind in general.

Mr. Chairman, Science has made a very long journey and lived a very eventful life since the days when Corpenicus propounded his theory of the " Round world ". From our current experience, Science may still travel further until perhaps through the development of Science itself, similar conferences are held on Mars or Venus and athletic and football meetings are held in some of the known planets. We may even see the day when visits to the other planets will be a regular and common practice. This idea may sound very unsound now but was not the Corpenicus idea that the world is round considered equally unsound and even blasphemous ? We live in times of great possibilities and we count on your contributions as Scientists to make the world a happy place.

Mr. Chairman, Ladies and Gentlemen, I wish you all, on behalf of the Osagyefo, a successful and fruitful Conference.

PRESIDENTIAL ADDRESS (ABRIDGED VERSION) 1961

by R. P. BAFFUOR,

Vice-Chancellor, University of Science and Technology, Kumasi

Honourable Minister, Your Excellencies, Nananom, Ladies and Gentlemen,

On this the first conference of the Science Association held publicly since its inception, I consider it a very great privilege indeed to address you as President and to welcome you to the deliberations and discussions that will follow.

This Association like all others in other developing countries, has a very significant role to play. This role falls upon Scientists, who in our daily walk of life perform functions scientific in character and who anxious to benefit from lectures and discussions, have gathered here in comradeship and in a spirit of cordiality.

This afternoon, we have heard Osagyefo's Address delivered by the Honourable Minister responsible for scientific development in which he has outlined the policy of development for education and scientific research which will serve to inspire us members of the Association into greater achievements. We are lucky for the establishment of institutions such as University Colleges of Legon and Kumasi by the Government and people of this country and for the confidence that has inspired the Government to spend so much on education.

We who are privileged to be workers in these great institutions and in all other institutions of learning in the scientific field must appreciate the tremendous responsibility that rests upon us individually and collectively in the development of the various tasks which the Government and people of this country have set before us.

Our role as members of this Association is like that of an Architect who spends long and laborious hours shaping and moulding the form of an edifice, setting it down upon paper, providing it with details and supervising its erection. When the work is completed he comforts himself with admiring the magnificence of his creation from a distance and turns his back to it to start off on another assignment. Ours is a task which takes us into the unknown which like the antennae of a Pilot's detector—the spearhead of an army—it probes into the unknown seeking and hunting for secrets of nature which lie hidden to Scientist and when he finds it chuckles to himself with pleasure, and passing it on to the world for its use, moves forward to probe yet further fields towards the unravelling of nature's store of scientific secrets.

And what is our reward ? As Scientists our reward is in the satisfaction of having sought and found the objects of our research and without elation or self-satisfaction, we dedicate ourselves to further tasks.

Our fellow Scientists in other countries are devoting more and more of their time towards research in the problems which face their respective countries. In Britain, America and Soviet Russia more and more Scientists are devoting themselves to the study of problems of science which would result in the betterment of the lot of mankind. In our little field and in our little corner of Africa, we of the Science Association of Ghana can play an equally important role. We have many tasks that lie before us. Many unsolved problems in agriculture, in medicine and in engineering which constitute obstacles against the steady development of our country. It is to these tasks that we should devote our attention and in doing so, let us remember that the prime basis of success is knowledge.

During my recent visit overseas, I talked with Professors in Europe and Britain and visited many institutions and was impressed by the significant sense of humility about the manner in which these eminent and distinguished Scientists and Professors set themselves to their tasks. Humble and unostentatious as they were it is clear that they possessed the great thing called knowledge. The knowledge that gave them confidence; the confidence that make them daring—daring to pursue into realms undreamt of—and it is this that brought them success. And so equally as these Scientists and Professors toil we too shall devote ourselves unstintedly to the

task of discovering answers to the many problems that face the development of science, engineering and agriculture in this country and having found them, pass-by with all humility and set ourselves again to fresh fields of endeavour.

This is our role. A simple and rewarding role, a role of creativeness which posterity will long remember for its significant contribution to a developing Ghana. Let us, therefore, take inspiration in the gathering of today and from the discussions that will follow during this conference and go back to our various fields of activity with renewed confidence and determined effort to achieve something in the course of the year.

Let me express the hope that when we meet again next year we shall come carrying in our hands the successes we have achieved in our research and in the study of the country's problems.

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OBSERVATIONS ON TRADITIONAL HEALING METHODS IN GHANA*

by W. S. MENSAH-DAPAA

Scientific and Educational Attaché, Nana Akonnedi's Shrine, Larteh, Ghana

I would like to express a wish—that in a not too far distant future Ghana could give the best in Traditional Healing Methods an open institutionalised chance to operate side by side with modern Medical Science. The observations which have given birth to this wish are what I propose to share with you.

Nearly five years ago, while I was occupied with research on Schistosomiasis in Ghana I was unexpectedly brought face to face with a phenomenon which shook the very foundations of all I had been brought up with. For the first time in my life I realised what a perfect stranger I had been all the time in my own Africa. I was stunned by the discovery but more than that I resolved, as a result, to investigate the underlying principles. I found what I was looking for at Nana Akonnedi's Shrine; before then, however, investigations on Witchcraft, Juju, and Spiritual Healing made tremendous demands on my personal earnings while at the same time exposing me to a number of serious risks to health, prestige and life. I have no intention of talking about these now. In this paper I want to dwell mainly on what I have observed at Nana Akonnedi's Shrine since December, 1959.

The Set-up and Ceremony

Nana Akonnedi's House at Larteh has a male section and a female section. The male section is the Court and the head is called the " Osofo "; all important cases are tried in this section. The female section has the " Okomfohene " (or Chief Priestess) as head. Both the Osofo and the Okomfohene have a number of attendants. The Okomfohene's attendants are made up of senior priestesses, junior priestesses, priestesses-in-training, herbalists, drummers and linguists. The priestesses are of every age and experience; in addition to those normally resident at Larteh many others are stationed in different parts of Ghana. The centre of all activities in Nana Akonnedi's House is unquestionably the female section.

It is perfectly normal to enter Nana Akonnedi's House and ask to see Nana Okomfohene Oparebea, the present Chief Priestess. The visitor is likely to be led into a waiting room in the female section and courteously asked by a linguist or junior priestess to state briefly why he wishes to see the Okomfohene. This done the Okomfohene will be informed. She will either ask that the visitor be brought to her or she herself will be led by her attendants into the waiting room where she has a special seat. Two bottles of Schnapps from the visitor plus a specified sum of money are presented to the Okomfohene; the visitor then formally greets her and she returns the greetings through a linguist. The visitor now restates his mission through the linguist and the Okomfohene's reply is relayed to him by the same process.

One of the bottles of Schnapps and one guinea are taken to the Shrine, a special part of the female section; the visitor is taken in there by the attendants; the Okomfohene enters when all are seated.

No one, except the Okomfohene, enters the shrine in any type of footwear. The shrine has three compartments; the Okomfohene alone enters the innermost chamber. When all preliminaries have been completed she rings a small hand-bell for a few minutes then pours libation into an earthen pot while praying on the visitor's behalf by narrating his purpose for coming to the Shrine. She looks intently into the vessel and then begins to speak aloud in Larteh; she speaks to the hearing of all in the shrine and the linguist passes the message on to the visitor. Having said all there is to be said the Okomfohene leaves the shrine and all the others follow.

*A Paper read at the first conference of the Ghana Science Association, April, 1961.

A visitor who goes to Nana Akonnedi's House and asks casually to see Nana Akonnedi will probably be met with strange looks at the worst or be told politely that Nana Akonnedi lives in the Spiritual World and that she visits the house by transfiguration in the Okomfohene once or twice a week on Tuesdays and Fridays. However politely the request to see Nana Akonnedi is made by the visitor such an action would be considered on a par with walking up to Buckingham Palace and asking to see the Queen; you cannot see Nana Akonnedi not only because it is improper but also because she lives in a world beyond your reach by perception or imagination.

Let us assume that the visitor arrives on a Monday night and that after having seen and talked to Nana Oparebea, the Chief Priestess, and having made observations on her normal behaviour and comportment he decides to stay till the next day. Early Tuesday morning, most probably before the cock crows, he is likely to hear an authoritative voice, quite unlike the Chief Priestess' chanting and calling out in Nana Oparebea's room something like this " Ye Yei! " The priestesses and everyone in the house wake up; they wash their faces and hurry into the room. The human form on the bed is still Nana Oparebea but the voice, the actions, commands and everything else are those of NANA AKONNEDI ABENA—in whose presence perfect discipline and precise observation of rites are the rule.

She changes some or all the clothes worn by the Chief Priestess for spotlessly white ones which are held in readiness; her special beads and sandals are presented and when she is dressed to her satisfaction she comes out led (followed by priestesses) walking slowly and majestically with all the authority symbolic of a Paramount Chief. Her state sword, " akofena " and a broom-like object are immediately presented to her; she powders her face and arms with " shire " for which there is a special bearer.

She walks towards the shrine, her path thither strewn with " shire " all the way. At the shrine she is presented with Schnapps some of which she pours on the objects she is holding and some at the back of her head; any drops on the hand are quickly wiped off by a special attendant. She leaves the shrine to sit in state in either the male section or a special part of the female section; usually it is the male section (known as her Court). Her official seat is a magnificent white African stool standing on sheepskin. When she sits in state she is flanked on either side by priestesses, Asofo, elders and visitors; immediately on her left sits a young girl carrying " shire " and standing on her right are two others one waving a big fan the other holding a piece of white cloth for wiping Nana's armpits at intervals. She is greeted one at a time and she responds three times to each; when she shakes hands it is always with the left hand. This is but a generalised account of Nana Akonnedi's transfiguration in the Chief Priestess, it is essential to note that she can arrive and conduct things in a thousand and one ways; she is extremely unpredictable. Even a brief account of how Nana Akonnedi conducts a court session is bound to overshadow the subject of healing.

Her day's sitting in court having been completed amidst singing, drumming, dancing and pomp, Nana departs. Her departure can best be visualised by going back to our imaginary visitor. He notices that towards the end Nana Akonnedi begins to say good-bye to all present, her dancing quickens in tempo, some of the attendants get closer to where she is standing or sitting: one yell, and she is gone. The Chief Priestess is now her normal self; she is led to her seat and water is brought to her. She washes her face and this brings her completely back to her real self.

Seldom does the Chief Priestess regain her normal self with the departure of Nana Akonnedi because invariably the latter is immediately followed by some members of her Spiritual Cabinet namely Nana Adade Kofi, Nana Essi, Mame Yaa Bosuo and Nana Kwaa Gyebi one after the other, each completely different from the other. There is no space to talk about them one by one and so, rather reluctantly, I shall briefly comment on Nana Kwaa Gyebi, or Asuo Gyebi as he is affectionately called.

The way and manner in which Asuo Gyebi makes his appearacne is better seen and witnessed than described; it is especially dramatic when it follows and, in fact, brings to an abrupt end Yaa Bosuo's jokes. All laughter is instantly stifled as his male voice thunders out " Eh Hmrr! " and

until he begins to greet and acknowledge greetings in a soft wheedling tone a serious atmosphere prevails. Asuo refuses to speak any other language beside Twi with a heavy Northern accent interspersing his speech with the exclamation " Eh hmrr ! " Nana Akonnedi speaks only high brow Larteh with the exclamation " Ye yei ! " Nana Essi speaks Fanti but can also resort to every-day Larteh, her characteristic exclamation being " Essei esse ! "

Yaa Bosuo speaks Fanti and is noted for her jokes. Only a handful of people understand the special Larteh which Nana Adade Kofi speaks; most characteristic of him is the exclamation " Kyeè kukuku ! " Nana Densu speaks Twi interspersed with " Yaw mesokyekyekye ! "

Let us assume that on the particular day in question Asuo's departure ends the day's festivities. The Chief Priestess's body which has been so active in dancing, talking and jesticulation from about 4.30 a.m. to 9.30 a.m. without the slightest sign of fatigue now rests wearily on a stool. After washing her face and drinking some of the water brought to her in a calabash she comes back to her normal everyday self. The fact that she has been completely unaware of all that her body has been doing since 4.30 a.m. is amply shown by the attentiveness with which she listens to a formal recount by the senior priestesses or the linguist. When everything has been reported to her she take the necessary action to implement instructions left by Nana Akonnedi or her children.

Healing at Nana Akonnedi's House is confined to the female section and it is mainly the responsibility of Asuo Gyebi, Nana Essi and Adade Kofi; it appears however that this portfolio has been specifically assigned to Asuo. No illness inflicted by witchcraft or juju lies beyond the reach of Nana Akonnedi's Cabinet unless it has been ignored too long to cause excessive damage and even then the patient could be pulled out if he has the means and the patience, or unless the malady is a punishment inflicted for an offence in which case treatment is dependent on confession as well as pacification of the offended. I should add that Nana Akonnedi does not hesitate to recommend that a patient, even a sick priestess, be sent to a hospital if it is found that the case can best be handled there.

Ceremonial Cleansing

Treatment at Nana Akonnedi's House is mainly with herbs, roots and barks of trees as well as a variety of preparations from these and other articles. Spiritual or ceremonial cleansing almost always precedes the herbal treatment. The articles required for the ceremonial bath are specified at the shrine when the patient takes his bottle of schnapps and the sum of one guinea there on his first visit. No two prescriptions are the same—for some the cost is high for others it is low; for some the articles called out from the spiritual world through the ceremonial vessel are few, for others many; for some it is prescribed that the ceremony should be in broad daylight while for others it may be at night under candlelight.

Each patient's case is determined by his or her specific problems, spiritual background and the day of the week on which he or she was born. When all the articles have been obtained by the patient, at a specified time, he or she is given a thorough bath with water containing herbs; after the bath the patient changes the wet piece of cloth for a clean and dry one; powder and perfume are then profusely applied all over the body. The patient is led to a seat and small cuts are made in threes at specific spots and joints of his or her body; a black powder obtained by burning certain herbs is rubbed into the tiny cuts. This ends the ceremonial bath; formal herbal treatment begins the next day.

Actual Cases

On 22nd July, 1960, a woman was admitted with the complaint that she had been married for six years but had no child. She had been under a Doctor's care and had availed herself of more than twenty medical examinations in hospitals. She had also tried eleven places for traditional aid. The husband had had children by other wives; she herself had on a few occasions missed her monthly periods by a month or two. Asuo prescribed the necessary articles needed to give her what she wanted. She obtained these articles and paid all her fees. The appropriate rites were performed and she was put on herbal treatment. For nearly three months she continued to report and to use the different herbal preparations. She is now five months pregnant.

Another woman who had been married for three years without a child left her husband and married another. A year after the second marriage there still was no child and so the second husband took her to Nana Akonnedi. She reported that during her whole married life she had never missed a period; she had taken every advantage of medical advice and treatment and had also tried a number of traditional healers. Her first visit to the shrine was in February 1960, after one of her fairly regular menstruations; it was to be her last for many months to come. The necessary rites were performed and a week later the couple left. Four months later it was a changed woman who returned to the shrine her belly bulging with a four-month old pregnancy. On 21st October, 1960, she had a normal delivery—a baby boy. I could not help sharing in her joy.

Two cases of women with disfunctioning sex organs have come under my observation. One was a young woman who was a woman in name but not in actual fact; her breasts were as immature as those of an eight-year old girl, besides her mensturation had been completely arrested because of the immaturity of the mammary glands. Asuo undertook to make her a normal woman. She went through the necessary ceremonies and abided by all the rules. She became a complete woman with fully developed breasts, was given in marriage, became pregnant and gave birth to a boy.

She has had another son lately. There is no likeness between what she is now and the creature that first entered Nana Akonnedi's House.

Sometime last year a man on his dying bed was rushed in at about midnight from an Accra hospital. He was a prosperous business-man and owner of a number of trucks and taxi-cabs. That night Asuo took direct charge by transfiguration in the Chief Priestess. In a week the patient who could not eat, speak or recognise anybody when he was first admitted was back on his feet. He was discharged ten days after his arrival and has since been going about his business.

I have witnessed treatment for epileptic, paralytic and mental cases as well as for habitual drunks. One paralytic was given his ceremonial bath and advised to seek admission to a hospital. Eye troubles, earaches, headaches and colds are treated with herbal preparations applied as eye, ear, or nose drops. Sores, rashes, muscular complaints and varicose veins are treated with smears of herbal preparations. Internal diseases are normally treated with drinks prepared from herbs, roots, and tree-barks. Cases of impotence in men are corrected with preparations mixed with gin, schnapps or other alcoholic drinks. Chest and throat complaints succumb to certain roots, herbs and tree barks; so also do venereal diseases.

The Role of the other Priestesses

Where do the Chief Priestess, the other priestesses and the herbalists come in ? The diagnosis is obtained from Asuo through the vessel in the shrine, and even after this has been done, he descends by transfiguration in the Chief Priestess and in the presence of all the other priestesses, linguists and herbalists he gives instructions by first stating what is wrong with the patient and what or who caused it; he next shows how the patient should be ceremonially bathed and calls out the specific herbs and other articles required. He states whether the preparations should be applied to the nose, ear, eye, skin, as an enema or taken internally. Usually there are more than one patient and for each he prescribes the appropriate treatment.

Everything that he says is taken down and as soon as he departs from the Chief Priestess the latter is briefed on what has taken place " in her absence ". She in turn authorises those responsible for collecting herbs to get what have been prescribed. What they bring must first be approved by the Chief Priestess before treatment proceeds according to the instructions left by Asuo. Any of the male attendants who applies himself diligently to instructions can eventually become a qualified herbalist.

Whatever Asuo does or prescribes is sanctioned by Nana Akonnedi and backed by Nana Essi and Adade Kofi; in a number of cases his treatments are in actual fact joint treatments by all the members of Nana Akonnedi's Spiritual Cabinet. Treatment at Nana Akonnedi's House is expensive generally but patients are allowed to pay the costs and fees when they are ready to do so.

Personal Problems in the Shrine

Nana Akonnedi has two serious headaches, the first is the rather paradoxical problem of a physician's inability to heal himself, the other is mainly a question of discretion and restraint in dealing with the human weaknesses of her priestesses and attendants. A priestess may be making mothers out of childless women while she herself is in dire need of a child. She cannot do for herself what she has been doing for others; she can, however, let someone else, perhaps from another shrine, help her in this respect. Most of the priestesses when in health difficulties take drugs recommended to them by pedlars sometimes with serious consequences because of their inability to read and write. What a decided advantage if an educated girl or woman could go through the training programme to qualify as a priestess. An ex-nurse or ex-midwife as Chief Priestess: how utopian, yet how desirable!

The other headache is the more disturbing of the two. All priestesses and attendants are expected to abide by all rules; priestesses under training must observe complete chastity. It is indeed unfortunate that they should all be typically human and subject to the weaknesses of the flesh and to temptation once in a while. Nana Akonnedi's present concern is how to modify her punishments to suit a changing Ghana.

Quite recently a sick woman came to the shrine and was told point blank that her illness was the result of her practising witchcraft. She made a clean breast of all her activities and requested that she should be freed from witchcraft so that she might live like any other normal woman. In direct contrast to this was a case which came up at the shrine not long after my arrival. One of the young priestesses took to practising witchcraft and went as far as attempting to harm someone under Nana's protection; she was caught and drastically exposed by Asuo. She was asked to confess everything, but she told only part of her story and left out the most damaging. Asuo pressed that she should show where she had hidden her articles of witchcraft but she denied having any. While she was wasting away in pain and agony she was given up to twelve noon of that particular day to surrender the articles asked for or show where she had hidden them. She persisted in her denial and obstinacy; by twelve noon she was no more.

One of the girls, soon after being given into marriage to one of the attendants committed adultery. She became pregnant but never mentioned her unfaithfulness to her husband. She believed herself safe until something rather unusual happened on the day she was to deliver. She had had a normal pregnancy and everybody expected a normal delivery. One hour followed another but there was no sign of the child. The girl's pains mounted from hour to hour, her groaning and agony were indeed alarming. Naturally Nana had to be consulted and it was learnt that the parturient mother had a confession to make and until that was done she would have neither child nor relief. No sooner had she finished narrating the whole truth about her unfaithfulness than the child dropped without any effort on the mother's part. Only a priestess, herbalist, linguist, Osofo, or attendant who does not value his or her life will deliberately do what he or she knows is not done at Nana Akonnedi's House.

Nana Akonnedi is never transfigured in a male; she has only one Chief Priestess at a time; the present Chief Priestess is Nana Okomfohene Oparebea of Larteh Kubease. If you ever decide to verify the facts about Nana Akonnedi be sure you are not taken to the wrong house or the wrong person, for there are people who will readily mislead you if they know you are a perfect stranger.

I have drastically summarised the set up and functioning of Nana Akonnedi's earthly and spiritual dominion. I have had to leave out studies on herbs and detailed accounts of how specific diseases are cured because my programme has not been completed.

Conclusion

Permit me to state in conclusion that there are many gaps in Medical Science as practised in Africa which could be filled by traditional healing methods. There are numerous gaps in African traditional healing methods which should be filled by Medical Science. It is essential to know where to start and with whom because in the first place there are many quacks, deceivers and pretenders who live on the reputation of their masters ; secondly there are many masters

who deliberately misinterpret what they know in order to make money; there is also the need for drawing a line between the herbalists on the one hand and Priests and Priestesses on the other hand. A herbalist dies with his knowledge but a priest or priestess doesn't because he or she is but the temporary earthly mouthpiece of a power that lives from generation to generation.

In trying to map out the lines along which Medical Science and Traditional Healing should work hand in hand in Ghana it is highly desirable to eliminate rivalry or subjugation of one to the other. Where a disease can be cured by both methods it would be worthwhile to find out which works quicker, safer and gives a more permanent relief. The classification and naming of all plants in Ghana if ever compiled by the Botany Faculty of the Ghana University would help immensely. A Medical School for Ghana without a Department of Traditional Healing would be most unrealistic and un-Ghanaian.

I am no authority on diseases prevalent in Africa, but this much I know, that not all diseases in Ghana are due to bacteria, viruses, spirochaetes, parasites, malignant tumours or nutritional deficiency. There are ailments in Ghana whose root cause can be found in witchcraft and juju. As long as there are people who indulge in these to victimise others, we may as well learn to render unto Caesar what belongs to Caesar and to Christ what belongs to Christ bearing in mind that even Caesar owes his powers to God whether he admits it or not. Nana Akonnedi is not against God, neither is she against Medical Science.

TUBERCULOSIS IN GHANA*

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In this paper I am not going to indulge in highly medical problems of differential diagnosis, bacterial resistance or such like but, I shall try and give you a brief but complete picture of the tuberculosis situation in Ghana and the problems involved.

Origin and Spread in Ghana

There is no historical information available as to how and when tuberculosis entered Ghana. According to surveys and outstation reports, however, we have formed the opinion that the disease has entered the country mainly from two directions. It might safely be assumed that European conquerors and early traders have brought the disease to the ports, from where it has been spreading slowly into the inner parts of the country. But we feel certain that tuberculosis has also been invading the country from the north. Nomadic tribes, some of them of Arabic or Semitic origin, others heavily mixed with non-negroes, have for centuries been trespassing across the northern borders and have finally come to settle there. It may even be that as early as the time of the migration of peoples following the collapse of ancient Ghana tuberculosis was carried in the direction of the south and south-west into the area which is Ghana to-day. That process must have taken centuries, and is still in progress. As the disease is spread by the infected and diseased human being only, natural barriers like water, swamps, jungle and deserts retarded migration of not only the people but of their disease, too. The more improved the means of communications through war and trade the more diminished was tribal seclusion, the easier tuberculosis finds its way. It should, however be noted that there are forms of tuberculosis the spread of which does not depend on the human being alone; some of these are tuberculosis of birds and tuberculosis of fish, but they do not play an important role. More important is bovine tuberculosis, tuberculosis of cattle, but to what extent this might have played or is still playing a role as a source of tuberculosis infection in Ghana has not yet been sufficiently investigated. It will have to be studied of course, before the breeding of cattle in Ghana is increased and consequently, local milk consumption goes up. But the main source of tuberculosis infection still is and will be man.

Distribution of the Disease

As long as a medical service has existed in Ghana tuberculosis has been diagnosed and treated. But treatment on a larger scale has become possible only since modern chemotherapy was developed, and before then the only treatment was bed-rest and surgery both of which were impracticable under the then existing conditions. So steps to organise a country-wide tuberculosis service were not taken until 1953 when the late Dr. Pointon-Dick, the first tuberculosis specialist in the country, started a tuberculosis clinic at Accra and tried to co-ordinate treatment at other hospitals. But shortage of beds, x-ray facilities and, above all, trained medical and nursing staff delayed the much desired rapid progress.

One of the necessary preliminaries to the building-up of a nation-wide tuberculosis service was to evaluate the extent of the problem. But there were very few reports and only small sample surveys were available. So in 1957 tuberculin skin-testing by which it is possible to assess how many have ever been infected with tuberculosis (without necessarily developing active disease) was started. Such tuberculin testing was carried out in 7,400 persons of all age groups at 45 places throughout Ghana. The results were very enlightening, indeed. Some very important facts were revealed. As you can see from Table 1, in both males and females a comparatively high proportion (25 and 28 per cent respectively) of those less than 5 years of age were already tuberculin positive, that is, are already infected with tuberculosis. The second important fact is the sudden rise of the percentage of positive reactors in the male group during the years from 14 to 19, namely from 40 to 63 per cent; that is, an increase of 23 per cent ! In the female

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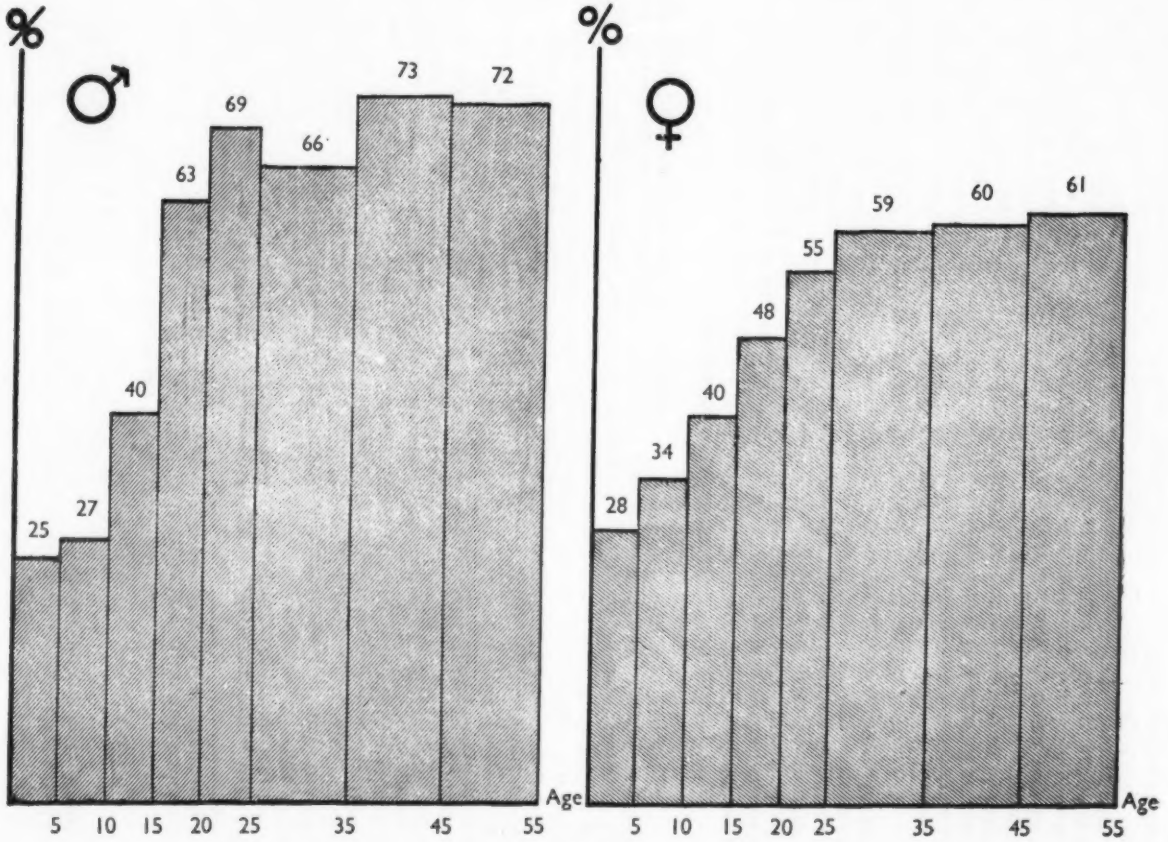
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Fig. 1

group the rise at this age is not so pronounced but still visible. The possible explanation of this lies in the fact that at this age (the puberty age) the majority of the boys leave home and school and come in closer contact with the general public. With girls it is not quite the same as they stay home longer. It is important to keep these two points in mind as I shall refer to them again when I come to consider prevention. Another interesting fact is shown by Figure 2 in which a comparison is made of the curves of positive reactions in three different areas: Southern Ghana/ Coastal Towns; Central Ghana/Forest Belt; and Northern Ghana. The curve of the Forest belt is evidently below those of Southern and Northern Ghana. What does that mean ? To us, it proves that even to-day tuberculosis has not yet penetrated into all parts of the forest belt. We feel convinced that if we were to survey far remote bush villages we would get a curve even lower than this.

Conditions for Infection

It is interesting to study the role of housing conditions and observation of principles of hygiene in the spread of infection. This is illustrated by Figure 2 which shows positive reactors among nurses and pupil nurses. These girls accepted for training as nurses, in general, come from improved housing conditions and more educated families where the children have less chance of being infected. And we see that in this group, at the age of 15 to 19 only 16 per cent were positive as compared with 54 per cent in the general population. But as soon as the young nurses are posted to actual nursing duties in the hospital where they come into contact with known and unknown tuberculosis patients, the curve, too, rises and rises to a percentage which is even higher than that in general population. Despite this, the morbidity rate among nurses is very low.

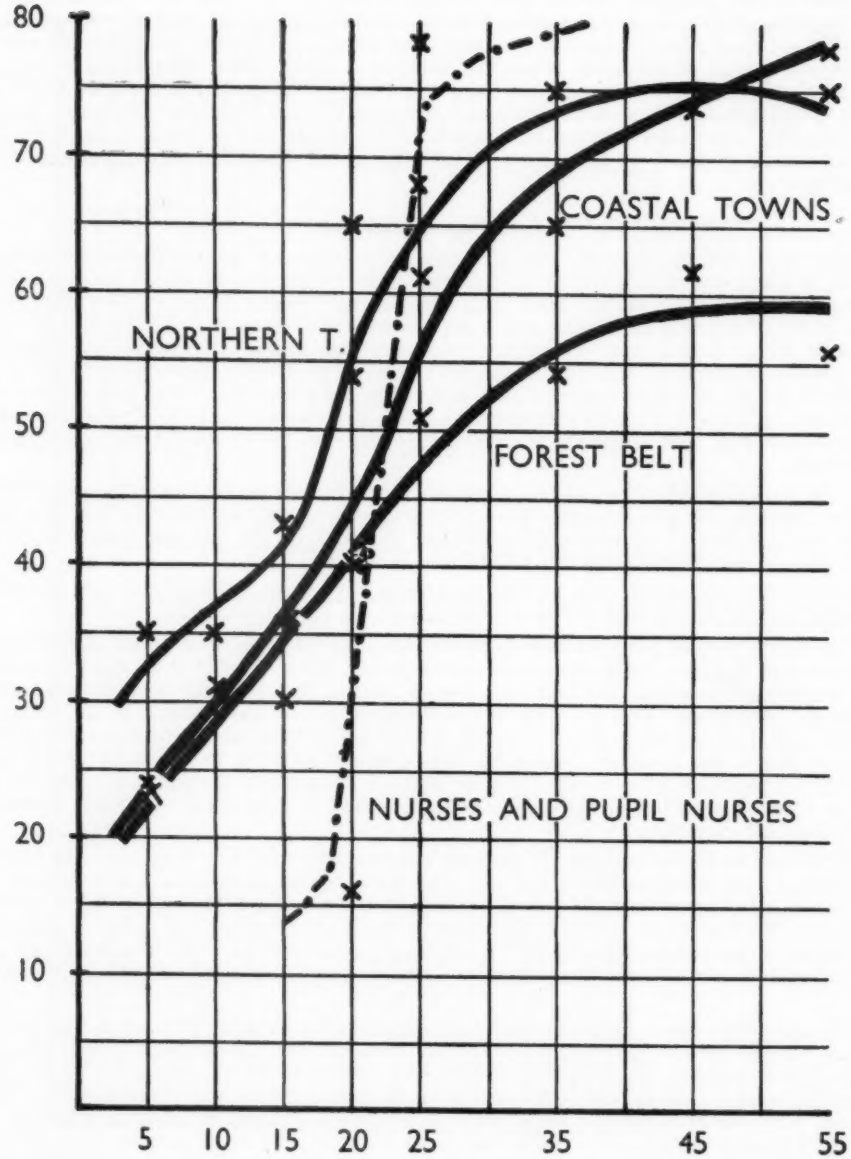
This shows that infection does not necessarily mean disease. On the contrary, a well endured primary infection will give a certain amount of immunity against re-infection, but, of course, the poorer the living conditions and the general resistance of the attacked human body, the greater the chance of developing active disease when attacked by it.

And so it is no surprise that we find the highest percentage of TB patients where the two factors of high infectivity rate and poor living conditions, come together.

During the past six years we have organized mass x-ray surveys all over the southern parts of Ghana and in Trans-Volta. Altogether approximately 54,000 people of all age groups have been x-rayed and assessed. We found an overall average of 1 per cent suffering from active pulmonary tuberculosis. That gives an idea of the magnitude of the problem we are facing, as it means that there are approximately 60,000 cases of active tuberculosis in Ghana which must be found, treated and if possible, cured. But our surveys show more. In one village in the forest belt only 0·3 per cent of the population were suffering from active TB, but in a village on the coast we found 3 per cent with open active disease! This shows where it is required to act immediately, fast and effectively.

That leads us to the question of what we can and must do. First of all we must find the cases and get them under treatment. But here already we are facing an obstacle. In many quarters tuberculosis is still considered not merely an infectious disease but a " juju "; so before patients come to us they have been attending native doctors and herbalists for some considerable time. Thus, many of the patients often come for treatment too late. In 1959 for example 31 per cent of the new patients seen at the Chest Clinic at Korle-Bu had blood-cough prior to first consultation!

The main difficulty in organising adequate treatment for as many patients as possible was the long distance between the patient and the doctor, apart from the shortage of beds allocated for the disease and the small number of personnel appointed for the work. In former days, tuberculosis patients had to travel for as much as 200 miles for chest x-ray, assessment and issue of drugs. That meant not only a lot of incovenience to the patient; but it costs him quite an amount of money which he often could not afford. Consequently many patients or prospective patients were prevented from attending regularly or attending at all. Besides, tuberculosis is not improved by long journeys on lorries over bumpy and dusty roads, and one open case on such a packed vehicle may be a danger of infection to all the others.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COASTAL TOWNS
NORTHERN T.
FOREST BELT
NURSES AND PUPIL NURSES

Fig. 2

Organization of Treatment

The first step in building up a Tuberculosis Service in Ghana, therefore, had to be to bring the clinic and treatment facilities as near as possible to the patient. A 5-year development plan was devised which provided Regional Tuberculosis Centres in each of the eight regions (*see* Fig. 3*B*) From these a system of District Tuberculosis Centres were to be established at all hospitals with x-ray and laboratory services.

Starting from the first established clinic at Accra, (*see* Fig. 3*A*) District Tuberculosis Clinics were organised at all government hospitals with x-ray facilities, and later at some of the mission hospitals. These places were visited regularly, usually, monthly, by the Tuberculosis Specialist who saw new or suspect cases and those old cases due for review. Up to 1959 10 district Tuberculosis Clinics had been organised. In 1959 more doctors with higher qualifications or at least some years experience in tuberculosis were engaged by the Ghana Government so that it became possible to open two more Regional Chest Clinics, at Sekondi for the Western Region, and at Kumasi for Ashanti and Brong-Ahafo Region. These have or are taking over the care of the District Tuberculosis Clinics of the region.

The Accra Chest Clinic is now serving approximately 5,000 tuberculosis patients from Accra, Eastern and Volta Regions with another 2,000 at six District Tuberculosis Centres at Winneba, Koforidua, Mpraeso, Worawora, Ho and Keta. The Tuberculosis Unit at the Kumasi Central Hospital has 4,486 registered cases. At present there are no District Tuberculosis Centres in Ashanti and Brong-Ahafo Regions, but one will be opened later in 1961 at Sunyani, the regional capital of Brong-Ahafo. The Tuberculosis Unit at Sekondi cares for 1,099 cases from Sekondi-Takoradi and Western Region, with another 1,050 at four District Centres at Cape Coast, Saltpond, Tarkwa and Dunkwa. Another District Clinic has just been opened at Axim. In Northern Region, the tuberculosis services are not yet organised, though all hospitals are treating tuberculosis. But the establishment of a Regional Tuberculosis Centre at Tamale is planned as soon as more doctors are available.

Altogether about 16,000 cases of tuberculosis are at present under treatment or observation.

At the three existing Regional Chest Clinics 113 beds are now available. At other hospitals beds are not set aside specifically for tuberculosis but might be made available when the need arises. Thus more than 95 per cent of tuberculosis patients have to be treated as out-patients.

The procedure normally is as follows; every patient suspected of having tuberculosis is sent to the nearest District Tuberculosis Clinic where he has a chest x-ray and a sputum test. The local Medical Officer prescribes an interim treatment until the patient is seen by the Tuberculosis Specialist or the Tuberculosis Medical Officer in charge of that region at one of his regular visits. Treatment is prescribed by him on stencilled report forms. With this the patient returns to his local hospital, where he receives his treatment in the prescribed dosage and for the prescribed duration. Later he is referred again to the District Tuberculosis Clinics for review.

Medical Staff.—At present, there are six doctors including one Specialist in Tuberculosis permanently engaged in the Ghana Tuberculosis Services. Of these, three are stationed in Accra, two in Kumasi and one in Sekondi.

Even after this development scheme has one day been fully implemented, the problem of tuberculosis will by far not solved. Still the majority of patients will be treated at home which means that infective people will remain sources of infection to others. Domicilary treatment is possible but it requires isolation of the patient in his home; he has to have his own separate bed-room which most families in Ghana simply do not have. So we must improve housing conditions. The patient has to use his own dishes and linen which must be sterilized regularly in boiling water. This is commonly not done, and he must be taught it. He has to have a protein-rich well-balanced diet which, in most cases, he cannot afford to buy as he often loses his job as soon as his employer finds out that he has had tuberculosis. There is no National Health Insurance Scheme or unemployment Insurance yet in Ghana, and the tuberculous employee finds himself in an awful dilemma. Either he follows his doctor's instructions and rests at home whilst undergoing treatment and allows himself and his family to get into difficulties and become unable

to raise the money for their daily food, or he disobeys his doctor's advice and continues work or resumes working before his disease is sufficiently stabilised. Tuberculosis is a disease which goes on for months and months, the minimum time required for sufficient improvement, even in an early and favourable case, is three to four months. So legislation on continuation of employment or financial aid in case of tuberculosis is an urgent need. Spitting on the ground anywhere and everywhere, badly ventilated rooms and untidy compounds are abetting spread of tuberculosis. So the public must be educated in the principles of hygiene.

All these have been started but it is not sufficient. The problem of tuberculosis must be tackled in a joint effort of Housing, Education, Legislation, Nutrition and, of course, Medicine.

From all the above it seems clear that treatment of the diseased alone cannot solve the problem which must be tackled from the opposite side as well by protecting the healthy from becoming sick at all. Passive means of protection as mentioned already (isolation and treatment of the disease, hygiene, and diet) must be supplemented by active protection in order to achieve a healthier generation.

Methods of Protection

There are two main ways of active protection:—These are (*a*) prophylaxis and (*b*) prevention. Prophylaxis in tuberculosis is in fact chemoprophylaxis which means that the same drugs used for treatment are given over long periods of time, to healthy persons in the hope that the high blood concentration of these chemicals will destroy the tubercle bacilli immediately they enter the human body so that no disease can develop. This method has several intercessors and is used in some countries. But I personally can see no point in such a prophylaxis. Is it worth administering acetylic acid for months and months to a whole group of population only because one day one or two of them might develop rheumatism. But apart from that, this method simply is not practicable under the conditions prevalent in Ghana.

That leaves us with prevention. And here, indeed, we have a really powerful weapon. By vaccinating BCG (Bacillus Calmette-Guerin after the two French scientist who developed this method) we cause an artificial but controlled primary infection which forces the human body to mobilize the defence forces. Thus, the body will be prepared when the real infection strikes. Reports from all over the world are very encouraging, indeed.

Equipment needed in this is very little; costs are not very high; vaccination teams can be small and mobile and thus able to reach almost every village; the vaccination technique is simple and quick, and so large numbers can be vaccinated in a comparatively short time. Finally it is efficacious and safe and compares favourably with any other immunological procedure. Despite occasional voices against BCG (ANDERSON, 1959) a great majority of those concerned with tuberculosis control problems are in favour of BCG. Reports from all parts of the world show its efficacy. HUTCHISON (1959) in England reported that in a 5-year period after BCG vaccination of children, he had not a single notification of pulmonary tuberculosis as against 19 amongst those unvaccinated. RERRIE (1959) in Jamaica observed a rapid decline of new cases after his vaccination campaign and out of 4,523 notifications in the 4 years following the campaign only 18 came from the vaccinated group. ARONSON (1958) reported a considerably lower death rate from tuberculosis in vaccinated American Indians (0·8 per cent) than in unvaccinated ones (4·7 per cent) over a period of 20 years. The British Medical Research Council (1959) was also able to show remarkable protection by BCG in a large scale school children trial campaign.

Encouraged by these and other favourable reports the Ghana Tuberculosis Services decided to initiate BCG campaigns on a larger scale whilst so far only contacts had been tuberculin tested and vaccinated routinely at Chest Clinic Korle Bu, Accra.

The ideal procedure would be a routine vaccination of all new borns and re-vaccination if necessary, at the age of about 10. Mention has already been made of the high infectivity rate in the 0 to 5 and the 10 to 20 age groups. Most authors agree that the puberty and pre-puberty

age is particularly endangered, and so in England a mass vaccination scheme was introduced by the Ministry of Health for 13-year-old children. POLLOCH (1959) and others advocate vaccination at the age of 10. Considered that puberty, in general, occurs earlier in the African and assuming that protection by BCG lasts for approximately 10 years, then vaccination at the age of six even seems justified for our campaigns. If for the start we would vaccinate all school children regardless of their age and after that vaccinate only the new school enterers each year the entire growing generation will be vaccinated and protected in a few years time.

We have started such a scheme already in Accra, and almost 30,000 school children of Accra primary and middle schools have been tested and vaccinated. A second campaign is well under way in Winneba/Gomoa district. At the same time we are training TB Nurses who will gradually take over TB Services in the districts and continue our vaccination campaigns.

Conclusion

This is the picture of tuberculosis in Ghana as brief and as accurate as I can give it. It is an enormous and complex problem tuberculosis in Ghana, and despite the very good progress made during the years past we are still far away from solving the problem. Great efforts have however been made and considerate development plans have been implemented. So it is hoped that in a few years time Ghana will be covered by a network of Tuberculosis Services Centres, dealing with treatment and prevention. With the aid of the other departments mentioned above, that is, Housing, Education, Labour Legislation and others it will be possible not to eradicate tuberculosis yet but to halt it. The fruits of our labour today will show in the next generation now growing up.

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PRESENT DISTRIBUTION AND STATUS OF TB. CENTRES IN GHANA

REGIONAL TB CENTRES—TB Specialist in Charge
(Accra, Kumasi, Sekondi).

DISTRICT TB CENTRES—With X-ray and laboratory, regularly visited by Regional TB Specialist.

(Axim, Tarkwa, Dunkwa, Cape Coast, Saltpond, Winneba, Keta, Ho, Worawora, Koforidua, Mpraeso).

LOCAL TB CENTRES—TB Patients treated but referred for assessment to nearest District TB Centre.

(Agona Swedru, Nsawam, Ada, Adidome, Akuse, Asamankese, Oda, Akwatia, Kibi, Hohoe, Sunyani, Bole, Jirapa, Kete-Krachi, Salaga, Damongo, Tamale,Yendi, Wa, Bolgatanga, Bawku.)

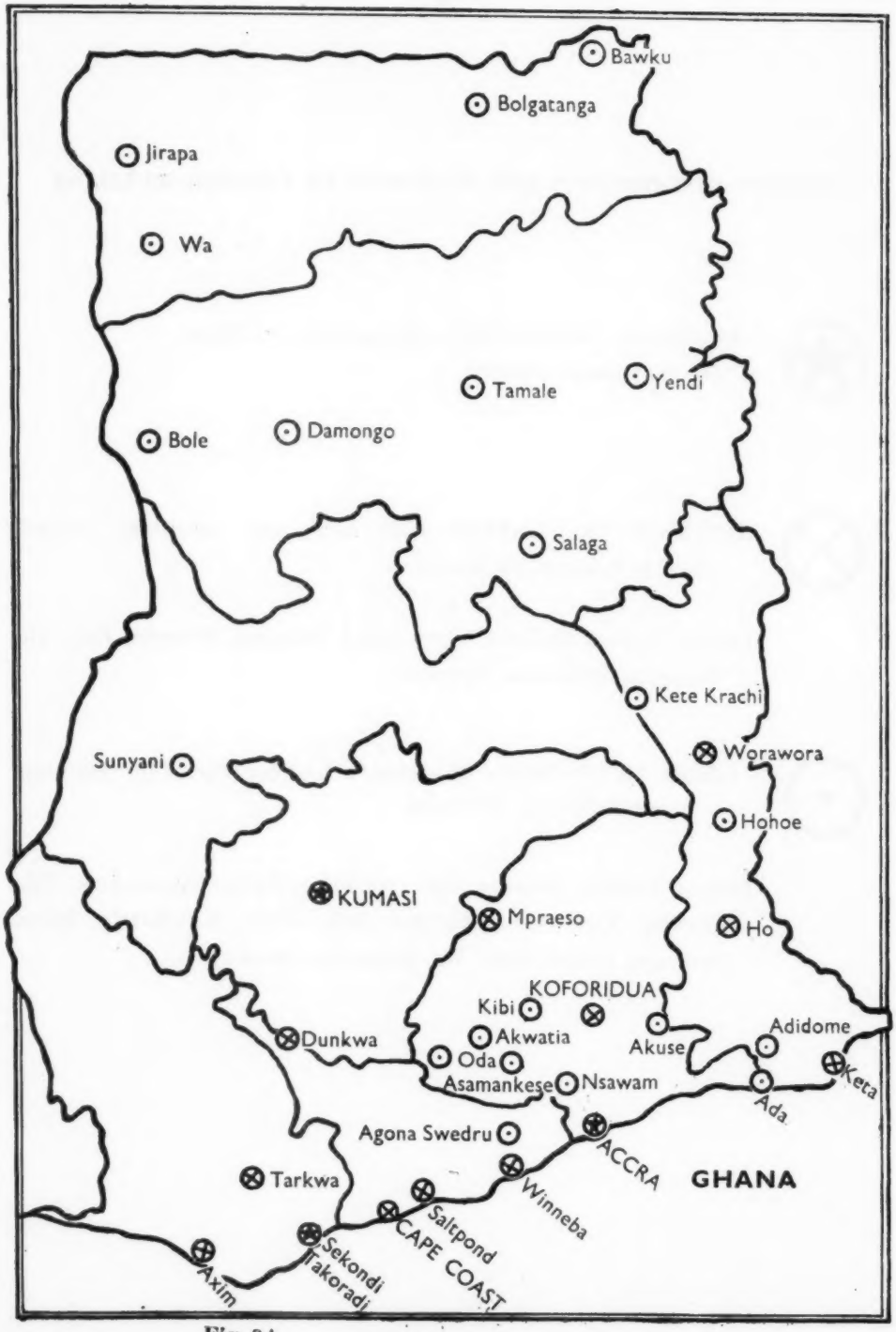

Fig. 3A

For Captions see page 25

Fig. 3B

For Captions see page 28

FUTURE DISTRIBUTION AND STATUS OF TB CENTRES IN GHANA

REGIONAL TB CENTRES—TB Specialist in Charge

Accra, Kumasi, Sekondi/Cape Coast, Koforidua, Ho, Sunyani, Tamale, Bolgatanga.

DISTRICT TB CENTRES—With X-ray and laboratory, regularly visited by Regional TB Specialist.

Axim, Tarkwa, Dunkwa, Saltpond, Winneba, Keta, Worawora, Mpraeso, Tema, Wiawso, Bekwai, Agogo, Hohoe, Mampong, Atebubu, Kintampo, Salaga, Damongo, Wa, Yendi, Bawku.

LOCAL TB CENTRES—TB Patients treated but referred for assessment to nearest District TB Centre.

Agona Swedru, Nsawam, Ada, Adidome, Akuse, Asamankese, Oda, Akwatia, Kibi, Bole, Jirapa, Kete-Krachi, Half Assini, Berekum, Dormaa-Ahenkro, Hwidiem, Wenchi, Kpandu, Bimbila, Walewale, Tumu.

RECENT DEVELOPMENTS IN THE CANOE FISHERIES IN GHANA*

by E. A. KWEI
Fisheries Officer, Accra

Introduction

In times past when fish caught was largely home-consumed and very small surpluses were smoked to be taken into the hinterland barely 50 miles away from the coast, fish supplies were apparently adequate, fishing effort was quite small, times spent not too great and quite a large crew was used. With the increase in marketing and distribution facilities due to improved roads and a greater demand for fish, improved efficiency was necessary on the part of the canoe fishermen to increase catches and compete with the increasing number of motor fishing vessels.

The existing fishing grounds are not convenient for a large part of the year and even during the herring season access to the shoals is not easy with the paddle and sail, the traditional means of propulsion.

All these considerations have demanded a much more mobile craft for the local fishermen to make fishing more profitable and to improve the range of the canoe. The Fisheries Division of the Ministry of Agriculture of Ghana, as has been done in Puerto Rico, Jamaica and other countries, experimented with the use of outboard motors on the canoes. These outboard motors were to be attached to the dug-out fishing canoes and other small crafts. This, it was thought would enable the fishermen to travel at speeds of up to 10 knots, and help them to gain easy access to the fishing grounds, enhance catches, reduce crews, and make them completely independent of wind or paddles.

Method of Attachment

The attachment of the outboard motors to the dug-out canoe presents quite a problem. The standard canoe in use in Ghana is of symmetrical double ended design, hollowed out from a single " wawa " (mahogany) log. The standard of craftmanship is excellent, and to construct a craft whose thickness is fairly uniform throughout without the use of any specialised tools but awls and axes must demand a high degree of skill. Very few of these crafts are completely identical but they are all able to do the job for which they were evolved, that is, to take the fishermen out through the surf to various fishing grounds and afterwards return them to their respective fishing beaches.

In addition to the design of the vessel a great degree of skill was required by the fishermen in running back through the surf which can be very violent. Any modification in design would upset this inherent quality and as such cutting a square transom was considered extremely inadvisable. As stated above, these canoes are for easy running in surf and their construction is based on parabolic principles which do not permit easy fitting of the outboard motor. Before coming to the experiments that have made it possible for the attachment of the outboard motor to the Ghanaian canoe, it would be appropriate to review methods that are in use in other countries with canoe design similar to ours. Unusual methods have often been used to attach these engines to the narrow round-sterned craft. In Angola, fishermen clamp their outboard motors on to an outrigger-type plank built across the stern of their dug-out canoes, as shown in Fig. 1.

*A Talk given at the first Conference of the Science Association, 1961.

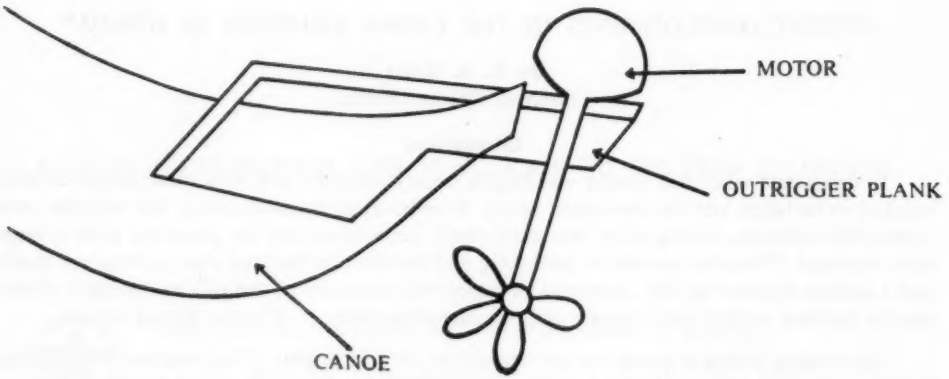

FIG. 1

In the Ivory Coast, fishermen use outboard in a well in the centre of the boat to enable them to get to and from the fishing grounds faster. (*See* Fig. 2). In view of the fact that Ghanaian canoes must work from beaches that are constantly subject to swamping, an inboard engine, as is used in the Ivory Coast, is quite a difficult proposition not to mention high costs and installation problems.

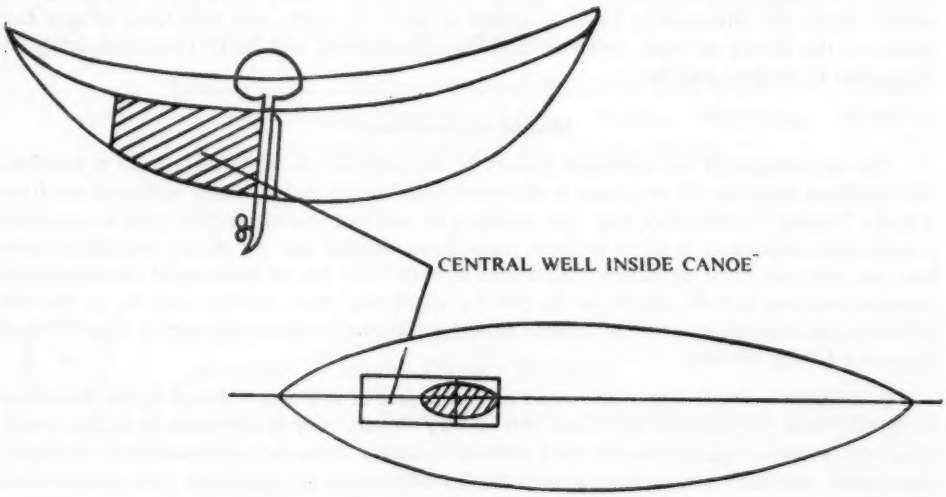

FIG. 2

The obvious solution was to fit an outboard engine which could be fitted and removed quite easily. The design of the canoe, however, does not lend itself to the fitting of these engines and three alternatives were possible:—

(*a*) By cutting off part of the stern to make a transom to hold the engine.

(*b*) By cutting a central well in the canoe and fitting sides to make a hollow box in which the engine could be fitted.

(*c*) By fitting a suitable side mounting if one could be devised.

(*a*) *A Transom to hold Engine.*—In considering this possibility, it is quite easy to cut off a portion of the stern in order to fit an engine with ease. The draw-back to this is that in so doing the canoe no longer has its original design and cannot be used effectively in surf. It must also be noted that " wawa " from which the canoe is hollowed has a tendency to rot, so that any fitting would have to be continually moved forward.

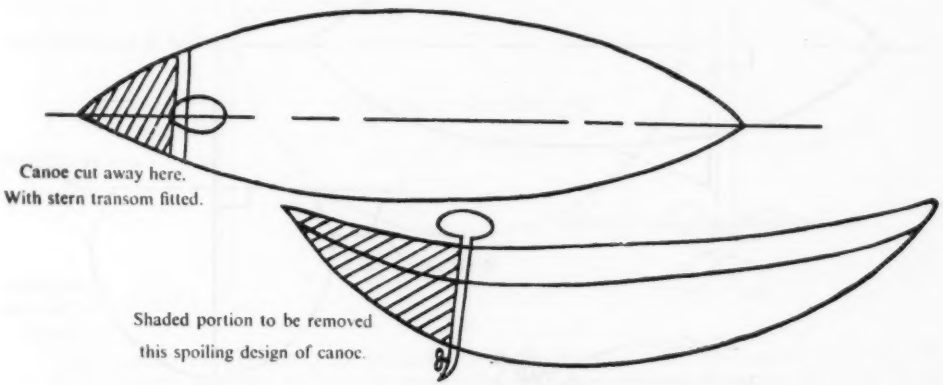

FIG. 3—(*i–ii*)

(*b*) *The Central Well* can also be made but this involves cutting out of the section of the bottom of the canoe to fit the well. Such a well would permit the installation of an outboard, but to be a strong fitting it would involve a considerable skill and expense. Once again the basic design would be altered, so that when an engine was not in use the central well would be a disadvantage. It also provides an obstruction to freedom of movement and when coming in through the surf the engine must be removed as it would otherwise foul itself on the seashore and be damaged as shown in Fig. 3 (ii).

(*c*) *The Side Mounting* had previously been tried but was abandoned as unsuccessful because such a mounting caused a canoe to spin round and was also very insecure often resulting in the engine falling off. It was thought that if a more suitable and strongly made mounting is made it may prove successful since side mountings have been used in other countries. In view of the shape of the canoe, a mounting had to be made which took into account several different angles to enable an engine to be mounted vertically and at right angles to the fore and aft line of the canoe while at the same time compensating for the tumblehome of the canoe gunwale (Fig. 4 (i)–(iv)). A roughly made mounting which took the form of three diamensional triangle was fitted to the side of the canoe, the base being used to take the engine. It was held in place by G-clamps and with either a British Seagull or 18 h.p. Evinrude or Johnson it worked quite successfully. It was obvious from the start that some method must be devised to counteract the tendency to spin round as a result of the lack of keel surface and the need for a very much stronger mounting since it came apart on one occasion. After several modifications had been carried out it was found that with the basic design reinforced by wrought iron (which was incorporated into the mounting bracket) and the whole mounting unit fastened to two boards, one on the outside and on the inside, an excellent fitting was obtained. When securely fastened, it would not be moved and it formed part of the canoe's side which was immensely strong.

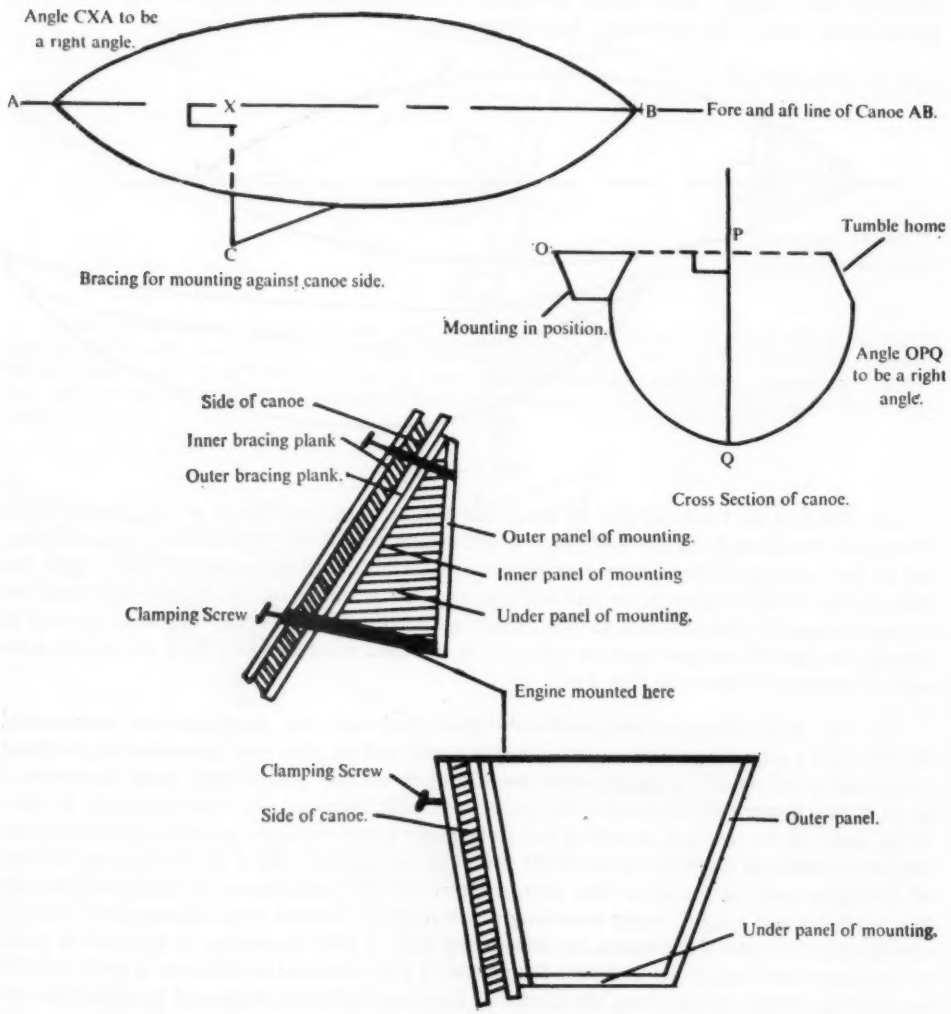
Angle CXA to be
a right angle.
A
X
B
Fore and aft line of Canoe AB.
C
Bracing for mounting against canoe side.
O
P
Tumble home
Mounting in position.
Angle OPQ
to be a right
angle.
Q
Cross Section of canoe.
Side of canoe
Inner bracing plank
Outer bracing plank.
Outer panel of mounting.
Inner panel of mounting
Clamping Screw
Under panel of mounting.
Engine mounted here
Clamping Screw
Side of canoe.
Outer panel.
Under panel of mounting.

FIG. 4—(*i–iv*)

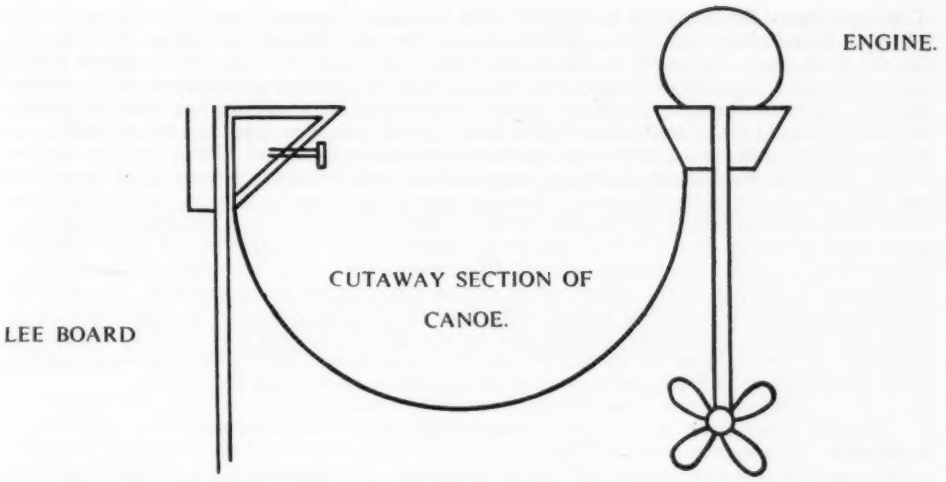

FIG. 5

The question of correcting the tendency to turn was dealt with after several trials by the use of lee boards fastened to the side to prevent the canoe drifting sideways from the wind. The best place to fit the board was found, after several trials, to be directly opposite the engine (Fig. 5).

The Scheme

Once a successful method of fastening the motor to the canoe had been devised, the scheme whereby it would be possible for the canoe fishermen to own the engines had to be worked out. The canoe fishermen are amongst the poorest in the Ghanaian community, a fact which has had to be taken into consideration in working out a satisfactory scheme. The best way out of course seemed to be a hire-purchase scheme. In its finalised form, the scheme requires that anyone who wishes to possess a motor must be a proved fisherman. This could be done by requiring that the chief fisherman of the particular area from where the applicant comes must endorse his application. A guarantor and two other referees are required in addition before an application form is approved. The applicant is then required to deposit 25 per cent of the cost of the engine plus an insurance premium and an installation fee. The Government then loans the applicant the remaining 75 per cent of the cost of the engine, a trader's discount of 10 per cent being allowed. The fisherman is to pay the amount loaned plus 3 per cent interest in 52 weekly instalments, that is, spread over a year. Should the fisherman default in his instalment payment on the engine, the engine is repossessed. There are a few fishing families who could manage, however, to purchase the motors outright without making use of the scheme.

An important help which is available to all fishermen has been in the setting up of classes in which fishermen get free instructions on how to operate and take good care of outboard motors. There is a further arrangement for regular checking of the equipment.

Operation of the Scheme

After everything has been arranged as outlined above, the next and perhaps the biggest problem was how to get this bright idea across to the fishermen. Demonstrations were arranged at the beaches of the various strategic villages. Talks were given at the end of each demonstration to explain the scheme more fully to the fishermen as to the benefits that they would derive from the scheme. At first the fishermen looked upon this new development with indifference, and were content with the primitive method of rowing and using sails which they have had for years. Those who would give the scheme a second thought were particularly scared off by the cost

of the equipment. Besides being perhaps the most law-abiding group of people in the community, fishermen would always think twice before entering into any financial agreement. This response was the same along the whole stretch of the coast from Axim to Keta. In the Accra region, fortunately, an enterprising fisherman was bold enough to purchase outright one of the motors for trial. His reward was an immediate success. His catches increased, the fish were much more fresh and he could make more than one landing in a day. The idea caught on others and by the the first half of that season, more and more people became interested. When the pilot scheme started therefore many more fishermen trouped in to seek information as to how they could own and operate the outboard motor. The fishermen in the Western Region, particularly Cape Coast were opposed to the use of these motors. Slowly, however, their opposition thawed as some people gave the motor a trial, and by the middle of the herring season a grave situation had developed. Many more fishermen applied for motors than could be supplied. Consequently, candidates for training in the classes could not be conveniently accommodated. But of more significance was the fact that the crew of more than 90 per cent of the canoes had refused to go to sea and deserted their canoes unless their owners had fitted them with motors. Meanwhile, those who saw the light earlier on and bought their motors were having their increased catches which were much more fresh and as a result getting better prices from the market.

Discussion

(*a*) *Results*

It is not so easy to compare the catches of the non-motorised canoes as a whole with the motorised ones, as by the end of the season only about a fifth of the canoes had been mechanised 1000/354. Taken on their own, however, the results shown by the mechanised canoes were spectacular, for, the mechanised ones more than quadrupled their catches and earned more than five times what a non-mechanised canoe earned. But above all the rush for motors, towards the end of the scheme when the money voted for the pilot scheme was exhausted, was more than indicative that the scheme had proved immensely successful.

(*b*) *Difficulties*

The implementation of the scheme was beset in many ways with difficulties. The response shown by the fishermen during the demonstrations made it difficult for the firms to order adequate supplies for distribution during the herring season as has been mentioned earlier on. Most of the boat owners were compelled by their crew to fit the canoes with outboard motors. Confronted with such problems, they were left with no alternative but to borrow, usually with fantastic rates of interest in order to pay their deposits. In effect therefore, the fishermen have had to pay two debtors at the same time while they had to look after themselves and their families as well as keep the canoes and fishing gear in sea-going condition.

The rush and pressure brought about by the sudden realisation to acquire motors made some of the trainees so excited that they were not attentive during classes. This over-anxiety showed itself vividly when these trained fishermen came to operate and maintain the motors themselves. Simple mistakes such as forceful removal of a plug often had serious consequencies and cost quite a lot of money to repair. The high cost of repair usually drove fishermen to do most unusual and funny things to their motors. Some fishermen, instead of taking their motors to the workshops of the supplying companies, took them to inexperienced automobile fitters who fitted car plugs to them resulting eventually in the destruction of the whole cylinder head. An engineer of one of the supplying companies had a shock in his life when he opened an engine to find it filled with palm-oil. This general lack of knowledge on the part of the fishermen needs correction by painstaking education if this mechanisation scheme is to succeed.

(*c*) *Improvements and Developments*

Experience gained from the pilot scheme, it is hoped, will help to bring about some improvements. It was, for example realised that the ordinary fisherman did not attach much importance to the regular servicing of his motor. Even when convinced to have his motor serviced, and the servicing is brought down to his door step, he does not understand why he should pay for it, whereas he would go to any trouble to have his motor repaired at whatever cost so

as to have the use of the motor. This state of affairs should be corrected, and it is planned to give subsidies to all fishermen who serviced their motors regularly and permitted the recording of their catches. This will be shown on a registration card when the real scheme comes into operation. Efforts are being made to provide the fishermen with safety chains for fastening the engines to the canoes as an additional precaution when the canoe capsizes, for experience has shown that the bracket may come off during an accident at sea and in many cases the motoı may get lost. It is hoped also to suggest to the manufacturers to fit their motors with governors, as the practice of running these motors at full throttle shortens the life of the engine.

Further, to help cut down the maintenance costs, trained fitters will be posted to key beaches to undertake minor repairs.

Conclusion

It is too early at this stage to predict the impact of motorisation on the fishing industry but the economics of the motor canoes surveyed shows that wider range and more trips, reduced crews and enhanced catches brought to the market in better condition, promise better times for the fishermen.

Technically, there is no reason why hitherto unexploited areas cannot be utilised. The use of power has permitted experimentation with improved nets such as purse seine lamparas. If these were applied to the whole canoe fleet, they could greatly increase catches while at the same time permiting the canoe fishermen to compete with the much larger powered craft now being introduced.

LIVER CIRRHOSIS IN PIGS IN GHANA

by D. ZWART

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Introduction

The Ghana pig industry is playing its part in coping with the rising demand for meat. This contribution of pork will certainly increase when by-products of the food industries like fish-meal, maize bran, brewers yeast, etc. will become available on a large scale for pig feeding. Jollans, at the Kumasi College of Technology showed that the native black pigs kept under semi-intensive conditions, had a good food conversion rate compared with European pigs and could reach an average of 60 lb. live weight within 20 to 24 weeks. The Animal Health Department in Pong-Tamale also became interested in the native black pig, but first in Kumasi, and later on in Pong, a serious liver cirrhosis became evident. This was first found in native black pigs, and at a later date, discovered in a few pigs of European origin. As far as now this disease is not a problem in the native pigs kept by local farmers under rather poor conditions.

Symptoms

In general, liver cirrhosis is characterised by a slow disappearance of the liver cells, and proliferation of the connective tissue, under the influence of toxic agents. These toxins can be derived from bacteria, fungi, higher plants or chemicals present in the food. The liver produces chemicals to detoxicate these toxins, and for this purpose the vitamins of the B group, vitamin E, sulphur-containing aminoacids and selenium are especially important.

Because the liver is damaged, the animal will also show clinical symptoms. In 132 of our pigs with cirrhosis, we found icterus in 18·7 per cent, ascites in 6·2 per cent and fatal bleeding in 5·2 per cent. Fatal bleeding is due to an increase in the blood clotting time. Apparently the liver is not capable of producing enough prothrombin for normal clotting.

Analytical Study

In trying to solve the etiology of this liver cirrhosis we had to consider the different factors mentioned above. At the same time the food had to be analysed for different vitamins, sulphur-containing aminoacids and trace elements. Unfortunately, due to lack of facilities here in Ghana, most of the food analyses had to be done abroad, and we are still without some important data. In general, it can be said that the rations producing the liver cirrhosis are too low in essential aminoacids and some of the vitamins, but high in fat. They contain a high proportion of maize or maize-bran. Trials were undertaken to investigate the possibility of the following causes of the disease:

1. *An Infectious Agent.*—Attempts to cultivate a specific organism from the liver lesions or other organs were unsuccessful. Secondary infections of *Clostridium tertiae*, *Staphylococcus aureus*, *Streptococcus spp.*, *Leptospira sejroe*, *Trypanosoma congolense*, *Ascaris lumbricoides* and *Stephanurus dentatus larvae* were sometimes found. Transmission to guinea-pigs was unsuccessful, also to splenectomised and non-splenectomised pigs.
2. *A Bacterial Toxin.*—A normal intestinal bacterial flora seems to produce toxins which, if the detoxicating chemicals are not present in the liver, may give rise to cirrhosis. An indication that this factor may be involved in our problem is that in a small trial, terramycin added to a ration that would otherwise have produced liver cirrhosis, gave full protection.
3. *A Fungal Toxin.*—Cirrhosis in pigs has been caused by maize contaminated by *Aspergillus flavus* and *Penicillium rubrum*. *Asp. flav.* has been found on maize in Ghana, and our rations at the Kumasi College of Technology contain 70 to 90 per cent maize bran. No trials have yet been done in this direction.

4. *A Plant Toxin.*—In the bark of a tree growing in the pig pen, and gnawed by some pigs, a great amount of alkaloid has been found. Other trees in the pig pen contain fair amounts of saponin in their bark. Further investigations are being carried out. The amount of bark eaten by the pigs is probably insufficient to cause cirrhosis.

5. *Lack of Essential Nutrients.*—Liver cirrhosis may be started by toxic products of various kinds, which cause the breakdown of the liver which has had its detoxicating properties diminished or eliminated by a deficiency of sulphur-containing amino-acids, vit. E, the vit. B complex, or selenium. Vit E seems to operate *in vivo* and *in vitro* as a biological reagent in delaying oxidations and so preventing liver damage. Food, during storage in the tropics, becomes rancid rapidly, with the formation of peroxides and destruction of vit E. The significance of methionine in hepatic injury is believed to be in its power to yield methyl groups which can detoxicate different agents. Very recently Schwarz has proved that the beneficial effect of sulphur-containing aminoacids is probably due to contamination with selenium. In order to investigate these theories, a basic ration was taken, which produced the disease in 70 per cent of 192 pigs. To this ration the following ingredients were added:

   (*a*) Basic ration, plus 0·5 per cent d,l-metheonine. Trial with 12 pigs; 10 affected (91 per cent).

   (*b*) Basic ration, plus 1·5 per cent d,l-meth. Trial with 6 pigs; 3 affected.

   (*c*) Basic ration, plus 0·5 per cent d,l-meth., vit. E intramus. weekly, plus vit B complex intramusc. 3 weekly. (The dosage was as recommended by the manufacturer). Trial with nine pigs; none affected.

   (*d*) Basic ration plus 0·2 ppm. selenium. Trial with 10 pigs; none affected.

   (*e*) Basic ration plus vit E intramusc. weekly. Trial with 6 pigs 6 affected. (100 per cent).

   (*f*) Basic ration plus 10 per cent skimmed milk. Trial with 43 pigs; 4 affected (7·3 per cent).

Discussion of Results

That skimmed milk was not giving 100 per cent protection was probably due to the fact that the basic diet at the end of the trial was already more than a year old. That vit. E was not having any effect is probably due to the fact that it was given by injection in too low a dosage to deal with rancid food. Whether the protective proportions of skimmed milk are a matter of its essential aminoacids or vitamins or both is not known.

It looks as if liver cirrhosis in pigs in Ghana is produced by different factors. We think, at the moment, that toxins derivated from higher plants, bacteria, fungi, or chemicals developed during storage will damage a liver that is predisposed for toxication due to an inadequate intake of essential nutrients. Some of these nutrients may have been destroyed during long storage under tropical conditions. There seems to be a genetic susceptibility to this disease, probably related to rapidly growing pig breeds. Much more information is needed to prove or disprove all these theories.

PROBLEMS IN THE ASSESSMENT OF COCOA VARIETIES

by D. R. GLENDINNING

W.A.C.R.I., Tafo

This paper outlines the types of problem that have arisen in assessing the series of new cocoa varieties at present under test in West Africa. These are hybrids between Amazon cocoa varieties and other types, and are of very high overall performance. I do not propose to deal with the individual varieties, which could make this paper of narrow interest, but rather with problems which could well be paralleled in many other breeding programmes.

Experimental Problems

The first set of problems are connected with testing the varieties under different climatic and soil conditions. This is necessary as we wish to develop varieties which can be grown with confidence throughout the cocoa areas of West Africa. In doing this we are limited by the difficulties in producing seed in large quantities in the early stages of the breeding programme, seed being obtained at present by hand-pollination between the original selected parent trees though for issue to the farmers it will be obtained from large seed gardens planted with cuttings taken from the parent trees.

To obtain accurate information as to which varieties do well in each set of conditions within the cocoa areas many trials are needed, and these should, ideally, cover the whole range of soil and climatic conditions concerned; heavy and light soils, well or poorly drained, fertile or less fertile; wet or dry areas, and long or short dry seasons, etc.; and they should also cover variation in cultural conditions, e.g. to clear-fell the land or to plant under forest shade; to give loving care and attention to the trees or to leave them to fend for themselves. This would require very many trials, and as the supply of seed is limited, each would then have to be very small. The expense involved would probably rule out the use of too extensive a series of trials, but as I am about to show, too small a trial is unsatisfactory in any case.

Cocoa in West Africa is grown at a close spacing, and neighbouring trees compete with each other. If neighbouring trees are of different varieties such competition will affect their assessment. A taller variety will overshadow a lower one, and competition between them in the soil may result in one robbing the other of soil nutrients.

If a wider spacing is used to avoid such competition, varieties which need a wider spacing than the farmer will give them will tend to be selected. It appears better therefore to plant plots of many trees of each variety, at the standard spacing, and in assessing the performance of the variety to leave out of consideration those trees around the outside of the plot which are in contact with other varieties.

Several plots of each variety are needed in each trial, for if there are few of each, apparent differences between the varieties may be due to differences in the fertility of the plots. I would not attempt to go into statistical theory, but will quote the following results from one of our best trials. This consists of ten varieties, each of which is represented by five 36-tree plots. The average yield was about 1,600 lb. dry cocoa per acre in 1959, and on the basis of statistical calculations it could be said that a difference of approximately 360 lb. per acre between two varieties probably indicated a real superiority of one over the other. This is a substantial difference in yield, but a lesser difference could not, with certainty, have been attributed to one variety being better than another as it could have arisen due to differences in soil fertility or other conditions.

We are limited then in the number of trials we can plant, and therefore must seek some compromise as to how to distribute them over climatic and soil conditions.

In Ghana we have simply planted trials on Division of Agriculture cocoa stations. These cover the country well in a geographical and climatic sense, and any variety which does well over all of the trials may be regarded as suitable for general distribution. If, however, a variety which does well at most sites does markedly less well at one, it may pose a difficult problem.

That site may differ in several respects from the others, e.g. it may be in a drier area, have a heavy soil, and have been clear-felled before planting. Which of these factors is the vital one that has set back this variety ? Would it be satisfactory in this area if planted under shade, or on a lighter soil ? Would it have done poorly in other areas if planted without shade ? A need for further investigation is indicated, but should the issue of the variety be delayed four or five years to permit this ?

In Nigeria where there are fewer Division of Agriculture stations, some of the trials were planted in selected areas where conditions were known to be marginal for cocoa due to severe dry seasons and relatively low rainfall. The results again may prove difficult to interpret in detail, but any variety which does well at these sites shows itself to be capable of surviving those difficult climatic conditions, and may justify immediate issue in those areas.

Besides the immediate information required from the trials of whether a variety is fit to be issued, information is also required to guide future plant breeding efforts. If a certain variety comes near the end of the series under test when grown in reasonable rainfall conditions but rises to about the middle of the series in dry conditions, it has no value for immediate issue but yet it is possible that it may have some factors for drought resistance which may make it of value in breeding to produce further varieties for dry areas. We are at a very early stage in our knowledge of cocoa varieties, and must seek every opportunity to glean this sort of information from the trials. To be certain that a relatively higher placing of one variety at one site than at another really means something, and is not just a chance effect, requires a yet higher degree of accuracy in a trial than is required for determining which varieties do reasonably well at each site. To allow such very accurate observations the number of plots of a variety at some sites has been raised to nine, and to permit this they have been reduced to 16 trees per plot, re-introducing the factor of competition between varieties discussed above. Yield records may be unreliable in later years because of this, and to offset this danger detailed records of vegetative growth have been taken in the early years before the trees were big enough to compete intensively. It has been found that close correlations exist between the vegetative growth of the varieties in the early years and their cropping a few years later, so that a lot of valuable information can be obtained from growth records alone (GLENDINNING, 1960). It is thought that the varieties can be calibrated in detail for the relationship between growth and yield in other trials planted in 36-tree plots, and the value of growth measurements may then become still greater.

Growth Rates

The vegetative record of greatest value is the stem diameter, and its rate of increase. Apart from fluctuations associated with variation in growing conditions this increase is roughly linear, that is if the increase over one year is two centimeters one may expect that over the following year, if the rainfall is about the same and shade conditions over the plot have not changed markedly, it should again be about two centimeters. This also implies that if one variety has an average stem diameter a certain amount greater than another variety at one date, the difference should be about the same at a later date if they are growing with equal vigour. This point is of great importance with cocoa, for it is rarely possible to plant seedlings of uniform size into a trial. The seed of cocoa must be planted immediately it is removed from the ripe pod, and pods ripen over a long season. It is not unusual in these trials for some seedlings to be from pods which ripened in September and others as late as January, and the effects of such a four or five month age difference may still be detectable when the trial commences bearing. In assessing their performance such effects must therefore be taken into account, and to compare the varieties for their rate of increase in stem diameter, rather than by the actual diameter at a given date, has proved a useful method.

The practical difficulties involved in getting the pods from WACRI to the trial sites with the seed still viable while having to send the pods as they ripen will be appreciated, especially when it is remembered that trials have been planted in various parts of Nigeria and also in Sierra Leone. Air transport has been much used.

Other vegetative records that are sometimes taken are height, and leaf number. Height ceases to be of value when the seedlings jorquette, that is, cease upward growth to develop a tier of branches. Leaf number is difficult to record when the trees reach any size, and is generally less useful than stem-diameter increase as it does not increase in a linear manner. It may be of some use when recorded before and after a dry season, to indicate the reaction of the variety to the dry season, but on the whole these records are less valuable than stem diameter records.

Yield Assessment

When the trials commence bearing, yield recording is required. Due to the long harvesting season this is not quite straightforward. Leaving aside the problem of inaccuracy due to theft, which should be overcome by adequate supervision, there remains the question of how frequently to harvest, for the recommended weekly harvesting to avoid heavy losses due to pod diseases is not yet the farmers practice. There is also a problem in that some of the more vigorous varieties tend to produce at least a few pods constantly throughout the whole year, and it is difficult to assess how much of the off-season crop would be economically harvestable by the farmer.

The vital factor in yield is of course the quantity of dry marketable cocoa obtained. To determine this precisely the wet cocoa should be fermented and dried, but to do this with the small quantities of cocoa obtainable from a given variety in each trial at each harvest is impracticable. Yields are therefore usually assessed from the wet weight of cocoa, presuming that the dry weight would be about 40 per cent of this value. It is becoming clear that this conversion is only approximately correct for the different varieties, some tending to give more and some less than this (GLENDINNING, 1959). Also there is variation in the proportion obtained at different times within the season, for the quantity of water in the wet cocoa varies, probably in relation to the rainfall. Fermentations are therefore carried out at WACRI whenever sufficient cocoa of a particular variety is available, and an attempt is being made to determine what conversion factor should be used in assessing the yield of each variety.

Ideally the wet cocoa obtained from each plot should be recorded, but in practice this would involve a great deal of work. It is done in some of the trials at WACRI, but in trials elsewhere it is usual to record the number of pods from each plot in a trial, and to weigh all the cocoa from all the plots of a given variety together.

In recording the number of pods from each plot, detailed records are taken of the number of these that are diseased or are damaged by rodents, and for each tree the total number of pods harvested is recorded. (This single-tree recording is necessary so that the yield from the inner 16-tree plots within 36-tree plots can be determined.) With so much recording at each harvest it is inevitable that mistakes shall be made, either in the actual recording or in the preparation of copies of the records to be sent to WACRI. To lessen the dangers of this a further record has been added to the list; when the cocoa is weighed a 1 lb. sample is extracted and the beans in it are counted. From this the average weight of a bean is determined, and this should be related to the average weight of cocoa obtained from a pod. The variation in pod weight, bean weight, and calculated number of beans per pod from harvest to harvest is then studied, and gross errors can be detected by wild fluctuations in these values. There is of course a tendency for these values to vary quite genuinely over the season, with larger pods, beans and bean numbers in the main part of the season than at the end, but such variation should appear relatively smooth. The bean size has itself some commercial significance, as will be explained later.

An intriguing problem arises in the assessment of rodent attack on pods. It is clear that in these trials the squirrels eat more pods of varieties that they prefer either for flavour or for an easily penetrable husk. If small plots of such varieties were planted by farmers in areas mainly planted with other less attractive varieties the squirrels may well descend upon them and cause excessive damage, but if large areas of such varieties were planted the limited local squirrel population could do no more damage than to an equal area of the standard variety. Conversely varieties which in these trials are little attacked cannot really be classed as resistant to squirrels, for it seems likely that if no more attractive varieties were grown nearby the squirrels may attack them equally heavily.

Quality Assessment

For a variety to be of any value the cocoa which it produces must be readily saleable. The British manufacturers have drawn up a list of factors to be considered, which list is I believe basically acceptable throughout the world (CAMPBELL 1947, C.S.A.C. 1959). It ranges from the flavour being acceptable and the percentage of fat in the bean being high, to the beans being free from commercial defects such as mould or excessive germination which tends to favour mould and insect infestation. Flavour is of course the most vital factor, but here the first snag arises. The type of flavour required differs from country to country, and from manufacturer to manufacturer within a country, according to the type of chocolate they make. Which type should therefore be aimed at ?

For most parts of West Africa, this problem is relatively straightforward. The cocoa at present grown is virtually all *Amelonado*, and in consequence the cocoa exported from the area is fairly uniform in flavour. This contrasts with other countries where many types of cocoa are grown, and the manufacturer, in order to know what type of cocoa he is buying, must buy directly from particular estates. The organisation required to establish such a system in West Africa would be enormous, and without it the overall market value of the West African crop may tend to decline due to loss of uniformity if mixed types of cocoa were to be exported. It is clear therefore that our criterion of flavour must be correspondence with *Amelonado*. Fortunately the *Amazon* types, which, like *Amelonado*, are *Forastero* cocoas in contrast to the *Trinitarios* and *Criollos* grown in some other parts of the world, have proved to be closely similar to *Amelonado* in flavour.

To assess flavour the first requirement is a satisfactory fermentation. Various methods of fermenting small quantities of cocoa in the laboratory have been devised, but the most dependable method is to ferment as the farmer ferments. This requires large quantities of wet cocoa, and from small experimental plantings these are difficult to obtain. Even when they are obtainable the product of a single fermentation cannot be regarded as completely reliable for assessment of that variety, so efforts must be continued to obtain further fermentations and compare the results from several. The situation has been somewhat improved by the development of a system whereby as little as 100 lb. of wet cocoa can be fermented, fairly reliably, in a tray in a " fermenting heap " consisting of several trays, the remainder being of the standard *Amelonado* or of other varieties (ALLISON and ROHAN, 1958). A number of 600 lb. heap fermentations may still be preferable as a basis of assessment however.

To assess what flavour has been obtained the best method is to consult the manufacturer. We are now in close contact with the British and American manufacturers, and also with a Swiss firm, and we hope to broaden our contacts shortly to include German manufacturers. Difficulties arise here however, due to the manufacturers differing in their requirements. The British and Swiss assess the variety primarily for correspondence to West African *Amelonado*, while the Americans have shown a tendency to upgrade samples with a hint of *Trinitario* flavour (as they use a great deal of *Trinitario*), and in consequence to downgrade samples not showing such characteristics and hence perhaps more similar to West African cocoa. To date this difference has not proved a serious difficulty, for the Americans have found the samples to be generally acceptable whether with the slight tendency towards *Trinitario* or not, so that the differences are only in finer details of preference between the varieties.

I should mention that we have facilities for small-scale preparation of chocolate samples ourselves, and that we make our own assessments before consulting the manufacturers. This is of value if only to avoid our wasting the manufacturers time with clearly unsatisfactory material, but more than this it assists us in understanding what the manufacturers are referring to in their reports. West African *Amelonado* cocoa gives a strong and fairly pure chocolate flavour, without pronounced fruitiness, and with some but not too much bitterness and astringency. Other types of cocoa, e.g. *Trinitario* and *Criollo*, tend to have additional flavours superimposed, and some may be weaker in chocolate flavour (VYLE, 1959). As it is always easier to add a different flavour than to remove one, it is clear that *Amelonado* cocoa is a very useful basic type

for general chocolate manufacture. It seems likely therefore that if other types of cocoa which amount to only some 10 per cent of the world's production were to be produced in much larger quantities, the premium in price which some of them receive may be lost, and their price may fall to below that of *Amelonado*.

Apart from flavour, other important factors are fat content, which is being watched in these varieties and in general appears to be as high as in *Amelonado* or possibly a little higher, and also bean size and husk percentage.

Bean size is of some importance in itself, in that the manufacturers like a fairly uniform size of bean for their preparation and roasting processes. This, in West Africa, would seem to mean that we should not depart too far from the bean size of *Amelonado* in our varieties. Apart from this, however, the manufacturers have come to associate bean size with husk percentage, finding that the latter rises if the average weight of the *Amelonado* bean falls below about one gramme due to seasonal variation. This is an important factor to them, as the husk is largely waste product. Husk percentage also is being watched in the varieties, and we find that where different varieties are concerned it does not correlate at all closely with bean size, and in fact one of our largest-beaned varieties may have a higher husk percentage than most. We will therefore give more attention to husk percentage than to bean size, though very small beans are still to be avoided. However the husk should not be too thin or it may become brittle and by breaking in transit favour the development of mould and insect infestation in the beans.

Looking back over what I have written I find there is one point I have omitted—the form of the tree. It is commonly said that the farmer can harvest pods up to 22 ft. from the ground, this being based on his using a 14 ft. pole and being able to add 8 ft. by reach. This harvesting is difficult however, and it would perhaps be best that the pods should mostly be below 16 ft. Some of our varieties are showing signs of becoming tall, but the trees are young as yet and their final height can only be guessed at. One which two years ago seemed to be threatening to get out of reach does not appear to have grown taller since then, so from this point of view we can only wait and see.

Summary

The difficulties in obtaining adequate coverage of the range of soil, climatic and cultural conditions in West Africa in a series of trials is discussed; this arises from the impossibility of providing sufficient seed for large numbers of trials of adequate size. The need for each trial to contain several plots of each variety, and for these plots each to contain several trees, is explained.

Difficulties in comparing the performance of the varieties within a trial due to age differences which arise from the need to supply seed as the pods ripen are explained. The value in this connection of comparing the growth rates of the varieties by means of the increase in stem diameter between successive recordings is discussed.

Difficulties in assessing the yield obtained are discussed; these involve assessing how much of the off-season yield would be economically harvestable by the farmer, and also deciding how frequently to harvest for disease losses to be comparable to those under peasant farm conditions. A further factor is the quantity of dry cocoa which could be expected from a given quantity of wet cocoa, for it is rarely possible to obtain sufficient cocoa of a variety at a single harvest of a trial for it to be fermented and dried. As a cross-checking system on the records collected the average weight of wet cocoa from a pod, the average weight of a bean, and the resulting number of beans per pod are calculated for each harvest. These values should not fluctuate widely from harvest to harvest, though there is a genuine variation over the season.

Assessment of quality is discussed; this requires adequate quantities of cocoa for reliable fermentations. The manufacturers are consulted regarding flavour, etc.; difficulties in relating their opinions due to different manufacturers requiring different flavours are discussed. Factors of quality other than flavour are also discussed.

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COMPARATIVE GROWTH RATES AND RESPONSES TO FERTILIZER OF *AMAZON* AND *AMELONADO* COCOA

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Introduction

As the writer is concerned with teaching plantation crop husbandry, it was thought desirable to establish early a small block of cocoa, at Kumasi College of Technology, though this had to be established on rather poor secondary bush, with rather droughty soils (of the Kotei series), which had recently been heavily food-farmed.

It was in fact considered both by local farmers and visiting experts somewhat foolhardy to attempt to grow cocoa with these handicaps. However, in the event, cocoa has been successfully established and is already bearing a few pods. This modest success is in itself of great educative value to our students.

Material and Methods

Mainly in order to introduce students to the techniques of simple field experiments, but in the hope also of discovering clues which would guide us in further field trials, it was decided to plant both *Amazon* and *Amelonado*, and to lay down a simple Random Block Fertilizer trial, on the two acres available, designed as shown in Table I below.

The cocoa was planted as basketed seedlings in 1st week of July, 1957 and was thus 32 months old in the field in early March, 1960 when heights were recorded.

TABLE 1.—LAYOUT DIAGRAM. ZZ—*AMAZON:* AA—*AMELONADO**

BLOCK I	Plot 1. Control	ZZ AA ZZ AA &, to 44 plants ZZ AA ZZ &c as for row 1. ZZ AA ZZ AA as for rows 1 and 2.
	Plot 2, Super 3½ cwt. per acre	ZZ AA ZZ etc. ZZ AA ZZ etc. ZZ AA ZZ etc.
	Plot 3, Am.phos. 3 cwt. c/ac + Mag sul.lc/ac	ZZ AA ZZ ZZ AA ZZ ZZ AA ZZ
	Plot 4, Am.phos. 3 cwt/ac	ZZ AA ZZ ZZ AA ZZ ZZ AA ZZ
BLOCK II	Plot 5 Am. phos. plus mag.sulph. Plot 6 Am. phos. only Plot 7 Control Plot 8 triple super	
BLOCK III	Plot 9 Am. phos. plus mag.sulph. Plot 10 triple Super. Plot 11 Control Plot 12 Am. phos. only.	

*Spacing is six feet in the (fertilised) row; nine feet between rows.

Three long rows comprise a plot of which only the centre one will eventually be pod-yield recorded. The arrangement of alternating pairs of *Amazon* and *Amelonado* plants was to provide twin rows at right angles to the fertilizer plots, giving a very obvious demonstration to students and farmers of the more rapid vigorous growth of the *Amazon*. Of course, most agriculturists are aware of the more rapid growth of *Amazon* cocoas but it is useful to have a numerical estimate of this, and it will be still more useful to have, in later years, a numerical estimate of the increased yield to be expected from *Amazon*, as compared with *Amelonado* under similar growth conditions.

It is realised, of course, that the more vigorous *Amazon* will shortly compete for root room and nutrients with the *Amelonado*, to an extent that will further slow down the latter's growth. This effect is however not believed to be of importance yet.

Block (I) was sited on what had been poor " bush ", and growth on this Block is markedly inferior, and supplying has been necessary on a greater scale, than on Blocks II and III where practically no supplying was needed.

It was thought that with only three replications, the chance was small of obtaining significant results from the fertilizer applications. However, the great virtue of cocoa as an experimental crop is that it stays on the ground, and data accumulates, for many years. It was therefore hoped that in 10 or 15 year's time results of interest would accrue from the fertilizer side of the trial. In the event, by end of 1960, quite striking effects from fertilizer had shown up.

The trial as a whole is also serving a most useful teaching purpose. First, in showing that, given care in planting and regular spraying against capsids, *Amazon* cocoa can be established without heavy losses on poorish soils, and in a climate subject to droughts. Secondly, it gives the students training in *careful observation and measurement*, the value of which, to agricultural students who will in their future employment often work unsupervised, can hardly be overstressed. Thirdly, it provides the necessary " local interest " in Statistical classes, and early introduces the student to concepts of variation in biological material. Fourthly, in this case purely by accident, it has shown students the importance of good establishment of shade, for the early growth of cocoa.

It will in fact be of great interest to see whether the early lead shown by Blocks II and III will be maintained. In our present state of knowledge it is unfortunately impossible to say whether the shade factor alone is responsible for the better growth on Blocks II and III. Probably these Blocks have better soil nutrient and soil moisture levels, because of a longer period under bush fallow, before the cocoa was planted.

One other interesting feature remains to be mentioned. Through Block III runs on old abandoned footpath, four to five feet wide, and worn down to one to two feet below the normal ground level. Wherever cocoa plants occur in this old pathway, growth is exceptionally vigorous. It is hoped in the near future to measure nutrient levels and moisture content of soils along this path to determine possible reasons for this.

A number of students carried out height measurements. All plots were measured at least twice, and some three times, and three were personally checked by the writer to ensure reasonable accuracy. This work has greatly assisted in assessing students' " reliability rating " in work of this nature.

Results

(*a*) *Growth Effects.*—The results on tree heights are shown in Table 2 below.

TABLE 2.—TREE HEIGHTS IN INCHES, MARCH, 1960 OF COCOA PLANTED (BASKETED SEEDLINGS) JULY, 1957

Block	*Plot No.*	*Treatment*	*Amazon*	*Amelonado*	*Diff.*	*Sum*	*G. Mean*	*Treatments*
I	1	C	44	33	11	17	38·5	C = Control
	2	S	50	29	21	79	39·5	77 + 109 + 29 = 315
	3	A/M	60	31	29	91	45·5	$\frac{315}{6}$ = 52·5″ = Mean.
	4	A	59	30	29	89	44·5	S = Super phosph. 40% at 3½ cwt./ac.
		Means	53·25	30·75	22·50	84	42·0	79+123=105=307
	5	A/M	67	37	30	104	52·0	$\frac{307}{6}$ = 51·17″ = Mean
II	6	A	56	28	28	84	42·0	
	7	C	64	45	19	109	54·5	A/M = Am.Phosph. 3 cwt./ac. + Mag. Sulph. @ 1 cwt./ac.
	8	S	66	57	9	123	61·5	91+104+116=311
		Means	63·35	41·75	21·5	105	52·5	$\frac{311}{6}$ = 51·8″ = Mean
III	9	A/M	70	46	24	116	58·5	
	10	S	68	37	31	105	52·5	A = 3 cwt./ac. Amm.Phosphate
	11	C	72	57	15	129	64·5	84+89+107=280
	12	A	66	41	25	107	53·5	$\frac{280}{6}$ = 47·0″ = Mean.
		Means	69·0	45·25	23·75	114·25	57·25	
		G. Mean	62	39	23	101	50·5	

It will be seen from Table 2 above that:—

1. *Amazon* cocoa grew to a height of over 5 feet while *Amelonado* reached less than 3 feet 4 inches.
2. Though there are big differences between Mean heights on Block I, as compared with Blocks II and III, the difference between types is much the same—22½ inches on Block I where growth was poorest,—and 23 inches on Block III where growth was best.
3. No differences due to manurial treatment were expected at this early stage and none were found. Pods are however already being borne and most of those on the trees in early March, 1960 when the height records were taken, were on the plots receiving triple super-phosphate.

The difference between growth on Block I and on the other two Blocks is very striking. Block I happens to fall in land which was carrying a poor growth of secondary bush, and had obviously been food-farmed more recently than Blocks II and III, where growth is good.

(*b*) *Manurial Effects.*—In this manurial/variety trial the plants were planted as basketed seedlings on 5th July, 1951. The results are shown in Tables 3 and 4 below.

TABLE 3.—FERTILIZER EFFECTS ON YIELD OF PODS, TO END DECEMBER, 1960

(Figures are numbers of pods harvested per one-sixth acre plot. C = Control, S = super-phosphate, A = Ammonium phosphate and A/M = ammonium phosphate plus Magnesium Sulphate.)

Block I				*Block II*				*Block III*				*Treatment Sums*		
C	S	A/M	A	A/M	A	C	S	A/M	S	C	A	Control ..	123	
												Super ..	250	
12	40	87	64	111	59	66	110	141	100	45	87	Amm. Phos.	210	922
												Amm. Phos. plus Mag. Sul.	339	
		203				346				373				

TABLE 4.—ANALYSIS OF VARIANCE

Factor	*D.F.*	*Sum Squares*	*Mean Square*	F	
Blocks	2	4,023·17	2,011.58		As F. from Table for P = 0·5 = 4·76 where $n_1 = 3$ and $n_2 = 6$ results are significant at much better than the one in twenty level, but do not reach the 0·01 point where F = 9·78.
Treatments ..	3	8,040·33	2,680·11	7·52	
Error	6	2,138·17	356·36		
Total	11	14,201·57			

For n = 6 in the t Table, t = 2·45. The least significant difference for any two Totals in the " Treatment Sums " table above is therefore $\sqrt{356{\cdot}36 \times 3 \times 2} \times 2{\cdot}45 = 46{\cdot}24 \times 2{\cdot}45 = 113{\cdot}69$. From this we conclude that ammonium phosphate is not quite significantly better than control, while the other two treatments are; we also find that the " ammonium phosphate-plus-magnesium sulphate " treatment is significantly better than the " ammonium phosphate only " treatment, and therefore conclude that magnesium is an element to which cocoa responds on Kumasi series soils. This finding will be subjected to verification in subsequent experiments. However the big response to phosphate is in line with the results of W.A.C.R.I. trials. It now remains to find what is the optimum economic dose of fertilisers and whether there will be the high positive interaction with reduction of shade found at W.A.C.R.I. To this end shade trees will be eliminated on one-half of the area.

Summary

In a random block trial at Kumasi College of Technology farm on rather poor soils and with rainfall rather below the optimum for cocoa, *Amazon* cocoa grew one and a half times as fast in the first 32 months in the field as *Amelonado*, and came much quicker into bearing (at 3½ years in the field *Amelonado* trees had yielded just a little over 1 per cent of the pods given by *Amazon* cocoa). Fertilizers used had no effect on growth as measured by heights of plants but there was a large yield response to phosphate, either alone as triple superphosphate or in ammonium phosphate. The response to ammonium phosphate was not quite significant (there were only three replications). Plots receiving superphosphate significantly outyielded control plots. Plots receiving ammonium phosphate were significantly outyielded by plots receiving ammonium phosphate plus magnesium (the latter carried by 1 cwt./acre of Epsom salts) and it is therefore tentatively concluded that cocoa responds to magnesium on these soils (Kumasi series). Further trials are planned to verify this and to determine the response of fertilisers in the presence and in the absence of shade.

The mean yield from all types of fertiliser combined was more than double that of control plots, a result which if it can be verified on a country-wide scale would have great economic importance for Ghana, where cocoa forms 98 per cent of agricultural exports and about two-thirds of total exports, in value.

CLASSIFICATION OF DARK COLOURED AND GREY CLAYS OF GHANA USING THE NEW UNITED STATES SYSTEM

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Resume

An attempt was made to classify some dark coloured and grey clays of Ghana on the lines suggested in the 7th Approximation of the new U.S. System.

The Black Clays of the Accra Plains, unquestionably, belong to the *Vertisols*. Similar dark coloured clays of Northern Ghana which were studied, are however, not *Vertisols*.

The Grey Clays of the Accra Plains, although similar to the Black Clays, cannot be appropriately classified as *Vertisols* but may belong to the *Aridisols*.

Introduction

Dark coloured and Grey, heavy, swelling clays of Ghana correlatable to the South African Black Turf soils, the Indian regur, Grumusols and Black cotton soils of temperate regions cover approximately 650 square miles within the coastal savannah areas (Accra and Winneba plains) and close to 100 square miles of the Interior Savannah region.

They occur over gently-undulating to flat topography (slopes generally below 2 per cent with occasional inselbergs around areas with a seasonally-distributed rainfall of 25–55 inches and a mean annual temperature generally around 80°F. Gilgai microrelief is not common and has only been observed prominently in the extreme south of the south-eastern coastal plains, generally of the lattice type of Hallsworth, et. al. (BRAMMER, 1959).

The characteristic vegetation is open (tussocky), medium or tall grassland with rare to frequent, scattered, fire-tolerant trees. The grasses, and sometimes the trees are generally of species associated with poorly-drained soils.

The dark coloured clays are invariably associated with basic parent rocks, mainly hornblende gneiss, amphibilite and actinolite schists, basic igneous rocks, Upper Birrimian (pre-cambrian) greenstones and from colluvium and alluvium derived from upslope. A typical profile consists of dark grey to black, heavy swelling clays, usually 3–4 feet deep, overlying weathered parent material. They are sticky and plastic when wet but become hard and compact on drying and develop wide vertical cracks. Lime concretions usually occur below 18–24 inches, but may be entirely absent in some profiles, especially of lowland areas.

The grey clays, the best known of which occur in the Accra plains, are developed mainly over the fine-grained acidic gneisses and in colluvium derived from pallid sands upslope. In the interior savannah areas they may be derived from more basic rocks (OBENG, 1961*a*). These comprise clays with approximately a foot of grey to brown, firm, sandy or silty loam abruptly overlying a layer of grey-brown, compact, impervious clay. Below these, there is a layer of pale-coloured plastic clay containing lime concretions, and usually a thin stone-line of gravel at the base of the clay overlying the weathered rock (BRAMMER, 1959).

The dark coloured and grey clays of Ghana are virtually undeveloped at present due to the fact that they are too heavy when wet and too hard and compact when dry to be cultivated satisfactorily with the native hoe. They are, however, considered potentially suited to development on a large scale especially within the coastal areas. With the aid of irrigation and drainage, artificial fertilizers, heavy machinery and large-scale methods of management, these soils could become highly productive.

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Essentials of the new United States Classification System

The United States seventh approximation on a comprehensive classification of soils differs essentially from earlier natural Classification systems because:

(i) The classification system is organised in such a way as to be able as far as possible to appropriately accommodate all soils of the world.

(ii) It is not so inadequately based on one or two of the factors of soil formation *per se* e.g. according to geological age of the rock formations; to glacial age of sediments and to those tied up to mode of transportation of soil materials; but on soil properties (reflecting all five factors of soil formation) that can be observed on the field or measured quantitatively in the laboratory. The classification system therefore places more emphasis on laboratory investigations (i.e. properties of the soils which can be observed by any competent soil scientist after making the necessary determinations) rather than on genesis as in earlier systems.

(iii) A systematic nomenclature is used employing coined words from Greek and Latin which directly refer to changes in the soil. The names selected are therefore easy to be remembered by workers in all phases of soil science.

(iv) And lastly the system is based on the properties of both virgin and cultivated soils unlike previous systems which were mainly based on the genesis or properties of virgin soils *per se*.

In the 7th Approximation six categories have been used. The six categories in decreasing order of generalization are, the Order, Sub-order, Great Group, Sub-group, Family and Series. The soil type used in earlier systems as the lowest category has been dropped.

Dark coloured and grey clays of Ghana may fall within two of the orders of the 7th Approximation, *Vertisols* and *Aridisols*. Characteristics of soils within these two orders are described in detail in the 7th Approximation (10).

In brief, the *Vertisols* include swelling clays which in the past have been referred to under various names, e.g. Tropical Black Clays (dark coloured Tropical clays), Grumusols, Black cotton and Grey and Brown soils of heavy texture, smonitza and at least a part of the Regur and Tirs, and some alluvial soils with large amounts of expanding lattice clays.

The common characteristics of *Vertisols* are: high content of expanding lattice clays, more than 35 per cent and usually more than 40 per cent; more than 30 milliequivalents exchange capacity in all horizons below the surface two inches; the ability to crack when dry; and with gilgai, or with slicken-sides close enough together to intersect in places. They may have a mollic or umbric epipedon or an argillic horizon, if the upper boundary lies within two inches of the surface. An albic horizon as much as two inches thick may overlie the argillic horizon. Calcic horizons and *Ca* horizons are common (SINGH, 1956).

The *Aridisols*, however, are primarily soils of dry places. They include most soils that have been called Desert and Red Desert soils, Sierozems, Reddish Brown soils, Solonchak, and some Regosols, Solonetz and Lithosols of dry climates. The common characteristics of the *Aridisols* are: soils that are usually dry when they are neither frozen nor irrigated and that have an ochric epipedon and one or more of the following diagnostic horizons—cambric, argillic, natric, calcic, gypsic, salic and duripans. They may also include soils with conductivity of the saturation extract greater than 1 millimho per cm. at 25°C. at some depths and/or those which are usually moist and have only a calcic, gypsic, or salic horizon (10).

Classification

(*a*) *Dark-coloured clays of Ghana*

The dark-coloured heavy clays occurring in the south-eastern coastal plains belong to the Order *Vertisols*. The dominant clay mineral as determined by various researchers is montmorillonite (BRAMMER, 1959; HAMILTON, 1955; STEPHEN, 1953). In the particular profile examined by BRAMMER and de ENDREDY (1954) the dominant reflections in oriented aggregates were

those of montmorillonite (basal 0·001), expanding from 14 to 17 Å upon glycerol treatment (MACEWEN, 1951) in a Ca-saturated sample. The only additional reflections observed in eight specimens were weak lines of quartz and possibly a trace of kaolinite. In accordance with the dominant clay mineral the soils expand and shrink considerably. The clay content is variable, but in typical profiles amounts to 30 to 60 per cent throughout the A horizon, but may show a definite peak at varying depths. The clay peak usually precedes the accumulation of calcium carbonate, although a typical calcic horizon within the A horizon is rare and if it occurs, it is in a transitional position to C. Accumulation of calcium carbonate in C is, however, very common and can reach as much as 40 per cent of the < 2 mm. fraction, in addition to concretionary $CaCO_3$.

The cation exchange capacities of the dark-coloured soils vary from 29 to 55 m.e./100g. proportionately to the clay content. The exchange complex is dominated by Ca and Mg in various proportions. In profiles containing free $CaCO_3$ throughout the A horizon the Ca:Mg ratio may be high, 2 to 4, while in the somewhat more leached but still neutral profiles it may be as low as 1. The ratio always narrows with depth. Exchangeable potassium is generally low, 0·2 to 0·4 m.e./100 g. The amount of exchangeable sodium varies considerably in the A-horizon, but never exceeds 5 to 10 per cent of the total exchangeable cations. In places, however, substantial amounts of exchangeable sodium may occur in the C horizon and in the decomposing rock.

The colour in the first 12 inches of the A horizon has values of about 3 to 4 when dry and 3 to 3·5 when wet and chromas ranging from 1 to 2 when dry and 1 to about 1·8 when wet. Distinct or prominent mottling is usually absent in the upland soils described above, but concretions of iron and manganese are frequent, in addition to a fair amount of finely divided manganese peroxide in the < 2 mm. fraction.

TABLE I

CLASSIFICATION OF REPRESENTATIVE MAJOR SOIL SERIES WITHIN THE DARK COLOURED AND GREY CLAYS OF GHANA

SERIES	Akuse/Lupu	Ashaiman	Agawtaw
FAMILY	Akuse	Akuse	Agawtaw
SUBGROUP	Orthic Mazaquertic-Grumaquert.	Orthic Grumustert	?
GREAT SOIL GROUP	Mazaquertic-Grumaquert.	Grumustert	Natrargid-Haplargid.
SUBORDER	Aquert	Ustert	Argid.
ORDER	Vertisol	Vertisol	Aridisol.

The content of organic carbon is low, varying from 0·7 to 1·5 per cent and the C/N ratio is usually high, 12 to 16. The colour, however, is associated with the organic matter (BRAMMER and de ENDREDY, 1954; STEPHEN, 1953).

As mentioned earlier, a degree of self-mulching has been observed but becomes prominent only after the first cultivation, and gilgai phenomena are rare.

Field and chemical characteristics of the dark-coloured clays indicate that the soils fall within the Sub-order, *Aquerts* (SINGH, 1956), on the basis of wetness reflected by the low chromas of the colour. On the Great Soil Group level the classification is somewhat more difficult. *Grumaquerts* must be prominently self-mulching but this is not generally the case. *Mazaquerts* on the other hand, lack self-mulching properties and they are massive or platy on the surface.

In respect of the dark coloured clays of Ghana, some self-mulching may be observed, but this is not prominent and the surface of these soils appears to be transitional between *grumaquerts* and *mazaquerts*. The authors are of the opinion that the most appropriate consideration will be to classify these soils as ruptic intergrades under a suggested Great Soil Group of *mazaquertic-grumaquerts*. Since the soils lack either an albic horizon within 15 inches of the surface or more than 15 per cent exchangeable sodium within a depth of 12 inches, they are classified on the Sub-group level as Orthic *mazaquertic-grumaquerts*, e.g. Akuse (A 169 and A 61) series*.

As the soils occupy an area stretching from southwest to northeast where the rainfall gradually increases towards the latter direction, some differences in the characteristics inevitably arise. In the extreme southwest with the lowest rainfall, soil colours may be somewhat lighter (10YR 4/2 when wet). The soils within this area can therefore be considered as transitional between *aquerts* and *usterts*. *Usterts* are dry equivalents of *aquerts* (Singh, 1956). Similar soils on the southwest border line are, however, definitely *grumusterts*, e.g. Ashaiman (B 96) series†.

In the northeast of the coastal savannah area, parts of Volta Region, the increasing rainfall leads to the development of soils which are basically *Vertisols*, but lack one of the essential characteristics—the clayey surface horizon. The A horizon of these soils is represented by 7 to 12 inches of light textured layer which is richer in organic carbon than the general average for the *aquerts* discussed above ($>$ 2 per cent C), followed by a clayey layer typical of *aquerts*. Soil colours are similar to typical *aquerts* and cracking can be very prominently observed, in spite of the light-textured surface horizon (1). A more detailed study is required with a view to appropriately placing these soils in the 7th Approximation.

In the adjoining lowlands of the areas of dark-coloured clays, dark soils occur which have been derived mostly from the upland soils. Their characteristics qualify them as *aquerts*. However, owing to their position, these soils have a higher content of organic matter (2 to 3 per cent C) than the *aquerts* described above and are distinctly acid. Soil colours are identical with the colours of the upland *aquerts* and even show the slight tendency of lightening in colour towards the southwest. No clay mineral determination was done in these soils, but comparing clay content with exchange capacity, it can be concluded that the soils may contain other clay minerals as an admixture (kaolinite or illite). The dominant characteristics of the soils, however, indicate montmorillonite as the principal clay mineral, e.g. Lupu (B 102) series*. In addition, the lowland soils frequently show prominent mottling, besides the dark colour.

Scattered patches of dark clayey soils occur also in the interior savannah area of Ghana. Although a number of these soils appear to be *Vertisols* (BRAMMER, 1959; OBENG, 1961*a*) and the clay content and colours support this classification, the dominant clay mineral does not appear to be prominently montmorillonite. Cracking is observable, but can be in cases attributable to the very high clay content alone (75 to 85 per cent in one case), and not to the dominant clay mineral. Although several detailed analyses of these soils are available, their classification is deferred until clay mineral data become available.

(*b*) *Grey clays of Ghana*

Together with the dark clays occur lighter grey clay soils both in the coastal and interior savannah areas, derived from less quartzose acidic gneisses (BRAMMER, 1961; de ENDREDY and BRAMMER, 1956) and basic rocks (OBENG, 1961*a*). These soils have a distinct light-textured epipedon about 10 inches thick, followed below this by a typical claypan layer with 30 to 35 per cent clay. In contrast, the light-textured epipedon contains only 5 to 6 per cent clay. The dominant clay mineral in the claypan layer is montmorillonite with some illite and kaolinite (de ENDREDY and MONTGOMERY, 1956; SOIL SURVEY STAFF, 1960). The light-textured epipedon has many characteristics of an ochric epipedon, except that its colour is somewhat darker than that of the C-horizon (wet 10YR 4/2 vs 2.5YR 5/2 in one example). However, the light texture and low organic matter content strongly indicate an ochric epipedon. As the underlying B-horizon can certainly be classified as an argillic horizon and with sodium definitely playing

*See Table.

†See Table 2 at back.

an important role in the exchange complex of the argillic horizon, further classification of the soils become rather indefinite. The combination of ochric epipedon and argillic horizon relegates these soils to the *Aridisols*, within the Sub-order of Argids (SINGH, 1956). The considerable content of water-soluble and exchangeable sodium, indicates that the soils are *Natrargids*, e.g. Agawtaw (B 1032) series*. This agrees better with the actual moisture conditions observed in the field. Unfortunately, most of the conductivity data refer to 1:5 water suspensions, which are not accurately comparable with the conductivity of the saturation extract. Actual determination of the extractable salts, however, indicate conductivities over 1 mmho of the saturation extract in the argillic horizon, referring these soils mainly to the *Natrargids* and slightly ruptic to the *Haplargids*. The corresponding grey soils in the interior savannah are even less well defined.

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*See Table 2 at back.

TABLE

Profile Number, Series and Great Soil Group	Depth ins.	Horizon	Munsell Colour Wet	Munsell Colour Dry	Particle Size Distribution (mm.) (%) NH Beaker, NaoH, 4 oH* Coarse Sand 2–·2	Fine Sand ·2–·02	Silt ·02–·002	Clay <·002	>2	Organic Matter C % W	C/ K
A 169 Akuse Series Mazaquertic Grumaquert	0–5·5	A1	10yr 3/1	10yr 3/1	20·8	39·3	7·4	32·5	0	1·74	16
	5·5–15	A2	10yr 3/2	10yr 5/1	23·9	30·6	7·3	38·2	·5	·84	14
	15–24	A3	10yr 3/1	10yr 5/2	12·4	34·1	9·3	44·2	4·0	·63	14
	24–30	A*ca*	10yr 3/1	10yr 5/1	9·4	30·8	9·8	50·0	7·2	·45	14
	30–41	C1*ca*	5y 4/1	10yr 5/2	12·9	24·8	10·0	52·3	53·0	·17	12
	41–48	C2*ca*	5y 4/1	2·5y 5/2	14·6	29·1	13·1	50·6	16·9	·09	
	48–57	R	5y 4/2	2·5y 5/2	22·1	38·1	11·4	28·4	1·9	—	
	57–72	R	5y 4/2	2·5y 5/2	25·9	49·2	10·7	14·2	18·0	—	
A 61 Akuse Series Mazaquertic Grumaquert (Somewhat ruptic to the Ustert Group).	0–4	A1	2·5y 4/2	10yr 4/2	15·3	25·4	9·9	49·4	5·2	·96	11
	4–13	A2	2·5y 4/2	10yr 4/2	13·0	24·8	9·8	52·4	3·0	·79	12
	13–29	A3	2·5y 4/2	10yr 5/2	13·0	22·4	10·1	54·5	9·8	·49	11
	29–36	C*ca*	5y 4/1	2·5yr 5/2	12·2	17·1	11·4	61·3	20·8	·41	13
	36–49	C2	5y 4/2	2·5yr 5/2	14·1	48·3	12·4	25·2	23·4	·10	9
	49–66	R	5y 5/3	2·5yr 6/4	24·6	51·5	11·3	12·6	28·6	—	
B 102 Lupu Series Mazaquertic Grumaquert	0–9	A1	10yr 3/1	10yr 4/1	2·0	9·7	13·2	75·1	<·1	1·77	14
	9–32	A2	2·5y 3/2	2·5y 4/2	1·0	5·7	10·3	83·0	<·1	·64	16
	32–72	C1g	2·5y 4/2	2·5y 4/2	5·3	14·9	13·1	66·7	<·1	·08	11
	72–78	C2g	5y 4/2	5y 4/2	8·3	13·0	9·7	69·0	<·1	—	
B 96 Ashaiman Series Grumustert	0–3	A1	10yr 3/3	10yr 3/4	11·1	19·5	69·4		·6	1·45	12
	3–10	A2	10yr 3/3	10yr 3/4	10·6	15·8	73·6		·6	1·19	13
	10–31	A3	10yr 3/3	10yr 3/4	16·8	17·8	65·4		2·9	·72	10
	31–36	C1	10yr 3/4	10yr 4/4	35·1	27·6	37·3		<·1	·25	9
B 1032 Agawtaw Series Natrargid (Slightly Ruptic to Haplargid).	0–6	A1	10yr 4/2	10yr 5/2	54·7	38·3	2·5	4·5	<·1	·34	13
	6–13	A2	10yr 4/3	10yr 5/3	52·5	40·5	2·5	4·5	<·1	·31	12
	13–19	B1	10yr 4/2	10yr 5/2	37·0	24·4	3·2	35·4	<·1	·59	11
	19–27	B2	10yr 4/2	10yr 5/2	30·3	31·5	5·8	32·4	<·1	·19	7
	27–40	B3	10yr 5/2	10yr 6/2	30·7	32·1	6·3	30·9	<·1	·14	8
	40–60	C1	2·5y 5/2	2·5y 6/2	24·2	29·8	9·5	36·5	<·1	·05	5
	60–74	C2–R	2·5y 5/4	2·5y 6/4	—	—	—	—	22·9	·04	6

*B 1032 Pipette, Hexametaphosphate

† Based upon sum of actions.

‡ Based upon exchange capacity.

TABLE 2

	Organic Matter		Cation Exchange capacity m.e/100g	Extractable Cations m.e/100g						Base Saturation %	pH 1:1	CaCo %	% Na in complex	Water-Soluble m.e/100g (1:5 extract)	
	C % W	C/N K		Ca	Mg	Mn	H	Na	K					Na	K
2															
0	1·74	16·9	39·8	21·5	12·7	·13	4·3	·6	·21	89·1†	6·4	·05	1·5	—	—
·5	·84	14·5	39·2	20·8	11·4	—	3·4	1·0	·17	90·8†	7·0	·09	2·7	—	—
4·0	·63	14·3	42·0	26·2	13·1	—	—	2·2	·20	99·3‡	8·2	2·2	5·2	—	—
7·2	·45	14·1	46·1	26·1	16·9	—	—	3·1	·21	100·4‡	8·3	15·0	6·7	—	—
3·0	·17	12·1	39·7	22·8	12·6	—	—	3·1	·13	97·3‡	8·4	18·8	7·8	—	—
5·9	·09	—	40·9	22·1	15·0	—	—	3·2	·20	99·0‡	8·4	12·1	7·8	—	—
1·9	—	—	34·0	19·6	14·0	—	—	2·8	·20	107·6‡	8·4	2·0	8·2	—	—
3·0	—	—	22·5	11·9	10·3	—	—	1·7	·17	107·0‡	8·6	·65	7·6	—	—
5·2	·96	11·3	52·8	34·4	17·0	—	—	·6	·24	99·4‡	8·0	1·5	1·1	—	—
3·0	·79	12·7	53·1	—	—	—	—	·9	·26	~100‡	8·1	2·8	1·7	—	—
0·8	·49	11·9	50·4	—	—	—	—	1·7	·15	~100‡	8·2	3·6	3·4	—	—
0·8	·41	13·2	52·6	—	—	—	—	2·8	·20	~100‡	8·3	17·8	5·3	—	—
3·4	·10	9·7	—	—	—	—	—	—	—	—	8·6	1·0	—	—	—
3·6	—	—	—	—	—	—	—	—	—	—	8·0	·75	—	—	—
·1	1·77	14·3	73·6	30·6	27·6	·15	9·8	1·2	·50	85·9†	5·5	<·002	1·7	—	—
·1	·64	16·8	73·4	33·6	28·9	·03	5·5	3·8	·17	92·4†	6·2	<·002	5·3	—	—
·1	·08	11·4	50·7	21·5	22·7	<·005	3·3	7·7	·18	94·0†	6·5	·02	13·9	—	—
·1	—	—	—	22·1	20·5	<·005	—	—	—	—	6·9	·03	—	—	—
·6	1·45	12·0	41·0	16·6	13·0	·13	7·1	1·2	·37	81·5†	6·3	·01	3·8	—	—
·6	1·19	13·0	41·9	17·5	13·3	·02	6·6	1·2	·15	83·0†	6·4	·02	3·1	—	—
·9	·72	10·0	31·8	18·3	13·4	·03	4·7	1·9	·15	87·8†	7·2	·02	4·9	—	—
·1	·25	9·6	25·4	11·4	8·9	·01	2·6	2·1	·10	89·6†	7·8	·02	8·4	—	—
·1	·34	13·1	3·5	1·4	1·0	<·005	1·4	·1	·06	64·6†	6·20	<·002	2·5	·2	·03
·1	·31	12·4	3·3	1·1	·8	<·005	1·7	·1	·03	54·4†	6·10	<·002	3·6	·1	·02
·1	·59	11·4	21·3	8·9	5·0	<·005	4·4	2·2	·22	78·8†	5·95	<·002	10·6	·6	·01
·1	·19	7·9	20·9	9·8	5·6	<·005	1·6	3·9	·15	92·3†	7·45	<·002	17·3	1·9	·01
·1	·14	8·2	20·3	12·0	5·8	<·005	1·4	4·1	·13	94·0†	7·85	<·002	17·5	2·3	·02
·1	·05	5·6	26·8	13·2	7·8	<·005	·8	4·7	·15	97·0†	8·15	·195	17·6	3·9	·02
·9	·04	6·7	—	9·4	7·9	<·005	—	—	—	—	8·35	1·20	—	·8	·02

THE CORRELATION OF FIELD, LABORATORY AND ANALYTICAL STUDIES OF ENGINEERING STRUCTURES

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Professor J. F. Baker of Cambridge once remarked that " In recent years engineering achievement, particularly British achievement in the technological field, has been decried by comparison with that in pure science. Few of the critics have any conception of what engineering is, far less of the complexity of a piece of research aimed at improving existing engineering methods. While the pure scientist, secure in the " disinterested " status of his research, can often follow the path of least resistance, skirting some nasty jagged rocks, the applied scientist has to concentrate on these difficult places . . . "

This introductory statement may have been a little unfair to the pure scientist, but the research engineer is sometimes envious of some of the scientists who can complete their research in the laboratory, where controlled conditions are almost ideal. Our main difficulty is that as soon as we attempt to apply results in the field we are confronted with conditions that can never be exactly predetermined. We can never predict precisely the conditions of loading, the properties of the foundations, the degree of homogeneity of the structural materials or the degree of reliability of either workmen or their supervisors.

In order to illustrate some of the problems of correlation an outline is given of a research programme which the author started at Leeds University, England, some years ago. Accounts which are of interest to engineers have been written up elsewhere i.e. (HARROP, 1956; RIZK, 1957; GLICK, 1957; LAU, 1959 and JONES, 1958) attention will be given here to aspects which might be of general interest to scientists. The technical title of the research programme may be given as " Composite action in multi-storey buildings " but some explanation of this is necessary for those who are unfamiliar with the engineering jargon. At the risk of considerable criticism from engineers who know something about the imperfectly understood problems of elastic and plastic behaviour and of the instability problems of frameworks it could be said that, given a steel framework one can, with a reasonable degree of accuracy, predict the stresses induced in the members by almost any known system of loading applied to the unclad framework. But as soon as the framework is encased in concrete and is combined with floors and walls the problem of predicting the stresses becomes much more complicated. In common design practice a number of assumptions are made that can result in somewhat extravagant although fortunately quite safe structures.

It was these problems that excited our interest but the real driving force was the promise of economy in design shown by some work that had already been accomplished. For example, under certain conditions it had been shown that the actual stresses could be as much as 30 per cent to 90 per cent less than those predicted by normal design methods. Briefly the history is that the Steel Structures Research Committee was responsible for a number of tests during the period 1929–36. This work was continued by the Building Research Station in England after the war. By developing a new form of strain measuring gauge that is permanently connected to the framework they were able to obtain a full stress history of selected members of government buildings at Whitehall. This was believed to be the first test on a building in which a complete stress record was made. These buildings had been designed for somewhat abnormal loadings. The project at Leeds University was made possible by the advice given by the Building Research Station. The programme involved the testing of selected portions of two steel-framed buildings and it is believed that this series of tests were the first of this type on buildings that were designed in accordance with normal design practice for standard loading conditions.

Both buildings had a concrete-encased steel framework supporting floors of reinforced concrete or hollow title construction. In the first building a total of 180 vibrating wire strain gauges were permanently fixed to beams and columns. In the second building some 270 gauges were fitted. These gauges were protected by cast iron covers sealed against the intrusion of moisture and encased by the concrete surrounding the beams and columns.

Strain Measuring Technique Diagram Gauge

Some of the details of this strain measuring technique should be of general interest. The requirements for the strain measuring device were that it should give reliable readings over a number of years when buried in concrete and read remotely and that when fitted to the steelwork before erection it should be capable of withstanding the rough handling of building operations.

In principle the gauge consists of a stretched wire held at its ends to the member under tests. The wire is made to vibrate at its natural frequency which is a characteristic of the strain to which it is subjected. If the member is strained the corresponding proportionate change of length of wire is registered by a change in frequency. The frequency of the measuring wire is measured by comparison with the frequency of a reference wire whose length can be changed by a calibrated control. The gauge length used for these tests was 6 inches. There is a standard form of this gauge which may be clamped to a test specimen and which makes contact by knife edges. This type could be easily disturbed and is unsuitable for permanent attachment. The gauge used was a modified form of the gauge designed by the Building Research Station. (Figure 1).

The permissible degree of tolerance had to be carefully considered both for the manufacture of the parts and for the methods of fixing the gauges to the test members. The posts carrying the wire were screwed into the member. The wire of 0·018 in diameter had to be specially drawn from a magnetic stainless steel and was of a sufficient strength not to creep under the working load. Recesses in the holding pins were arranged so that the wire was gripped firmly enough to avoid slip. The dimensions of the grips were quite critical, any inaccuracies resulted in a broken wire or slip. The wire is vibrated by discharging a condenser through a small electromagnet. This magnet picks up the vibration as an oscillating electric potential which is fed to the cathode ray tube of a Maihak recording instrument. The reference wire of the Maihak instrument is maintained in continuous vibration at its natural frequency and can be strained by a micrometer screw acting through a lever system. The technique for matching the frequencies of the measuring wire and the reference wire involves the use of the characteristic Lissajou figures.

The reference gauge of the Maihak recording instrument was calibrated against the vibrating wire gauges mounted on a 2-in. square section column carrying one gauge on each face. Direct compression and bending tests were made, using mechanical gauges to check the accuracy of the vibrating wire gauge. The mechanical gauge incorporates a mirror that deflects a light beam: it is a particularly reliable instrument in the hands of skilled experimenters.

The accuracy that can be obtained with the vibrating wire gauges over a long period depends on a number of factors: variation of vibration frequency caused by dirt on the wire, variable excitation or damping of the wire because of inaccurate setting and differential thermal movement relative to the strain of the test number. Dirt was largely eliminated by protecting the gauge with cast iron covers, but it is surprising the amount of magnetic debris that gets to the pole pieces in spite of rigorous precautions. A whole host of troubles did arise but were gradually eliminated. It is reasonable to claim an overall accuracy of + or — 10 x 10–6 strain for long term tests. This represents about + or — 300 lb./sq. in. stress. This is not acceptable for the usual range of laboratory tests but it was quite satisfactory for the field tests as the working stresses are of the order of 8 to 10 tons per sq. in. There are also thermal effects on the gauge because of the different coefficients of expansion of the wire and the member, the resulting error corresponds to a stress of 30 lb./sq. in. per degree F. variation in temperature. Differential heating of the wire and of the member can also give rise to quite serious inaccuracies in strain readings; this can easily be demonstrated in the laboratory but as the gauges in the building were protected by the cast iron cover and the concrete casing this type of error is insignificant.

The organisation of the drilling and the tapping of the holes for the gauge posts and the installation of the gauges was an exercise that involved many hours of planning with the consultants and contractors and many hours of field work at most inconvenient times and in most unfavourable conditions. Some persistent efforts in amateur applied industrial psychology

established excellent co-operation between the constructional workers and the research workers. The importance of establishing the proper relationship cannot be overstressed because any careless or deliberate unco-operative action could have resulted in a complete failure of the tests.

Field Tests

The observations may be divided into two classes: the development of strain during the building operations and the strains measured during the live load tests. During erection of the steel framework the manipulation of the frame can cause stresses, usually they are fairly low. The highest recorded erection stress was about 6,000 lb./sq. in. This was exceptional and took place in a member that was not likely to be subjected to any substantial live load stresses.

After erection of the bare frame, tests were made to demonstrate the elastic behaviour and to verify the reliability of the vibrating wire strain gauges, and to examine the degree of rigidity, obtained in practical bolted joints.

The continuous observations made during erection and concreting revealed some of the effects of concrete shrinkage which can induce compressive stresses in the steelwork. (*See* Figure 2). Some of these stresses are relieved by the fine cracks that normally form in the tension zone of reinforced concrete under working loads. Figure 2 also illustrates the change of stress in the bottom flange after the live load test.

Live load tests were made by jacking between beams and also by applying distributed loads over the floors. It would take too long to describe all the difficulties involved in making the live load tests, not the least of which was finding a time when the test could be conducted with the least disturbance to and from the work that was still going on in the building. The greatest difficulty was that of devising tests that would give some estimate of the effect of the greatest possible working load on the structure. It was quite impracticable to load the building completely.

Some idea of the results can be obtained from the diagram, Fig. 3, which shows a comparison of the observed and the design stresses. These diagrams were made for engineers and some explanation is necessary before too much is read into a direct comparison. The diagram shows the stresses developed in the same two beams with the load applied in different positions. Moreover an estimate of the effect of loading a number of bays simultaneously is not a matter of simple addition because of the method of testing. A first load on a reinforced concrete structure results in certain residual stresses caused by initial development of fine cracks below the neutral axis. The estimate of the effect of loading a number of bays at once had to be built up after a number of secondary tests had been made to evaluate the extent of what is called for convenience the " carry over " effect of loading a bay remote from the beams under test. The most generous estimate that was made, gave stresses that were only 65 per cent of the design stresses.

In order to be quite fair to the design engineers it must be emphasized that the design was based on standard codes of practice. There are known refinements of design but it is not always economical in the long run to consider these refinements; sometimes the clients have a habit of asking for approval of higher loads often before the building is complete. Furthermore the refinements may be exceedingly difficult to apply and there are often doubts about the reliability of design methods that have been developed on the basis of laboratory tests. The field has the habit of introducing new imponderables. These problems justify the investigation. In fact the primary theme of the research programme was to make comprehensive analytical studies but from these to develop simple design rules that can be fairly easily applied in practice. The results of these investigations are applicable to both steel framed and reinforced concrete framed structures.

Analytical Studies

Several theoretical studies of both elastic behaviour and plastic behaviour were made while the full-scale tests were proceeding. Plastic behaviour can only be considered relative to collapse loads: collapse studies were confined to the laboratory !

The basis of the classical analysis of the elastic behaviour of laterally loaded plates is well known. The difficulties arise out of the problems of dealing with the variety of edge conditions, these edge conditions themselves are controlled by the behaviour of the adjacent slabs.

The basic differential equation for laterally loaded plates is $D\nabla^2\nabla^2 w = q$, where q is the intensity of load: w is the deflection: the laplacian operator for the variables is $\nabla^2 = \frac{d^2}{dx^2} + \frac{d^2}{dy^2}$; D is a measure of the stiffness (or what is often called the flexural rigidity) of the slab given by $D = \frac{Eh^3}{12(1-v^2)}$; where L is the slab thickness; E is the nodulus of elasticity and v is Poisson's ratio. The equation is usually expressed in the form: $\frac{d^4w}{dx^4} + 2\frac{d^4w}{dx^2dy^2} + \frac{d^4w}{dy^4} = \frac{q}{D}$

In order to make the problems manageable the following basic assumptions were made:

(i) the slab is of homogeneous, isotropic and elastic material and is of constant thickness " h."

(ii) the beam is attached to the slab in such a way to undergo the same deflection as the edge of the slab;

(iii) the neutral axes of the beam and the slab coincide;

(iv) the direct stresses in the beam and slab are absent.

The one common characteristic of all these assumptions is that they are not strictly true. This work is still continuing, in fact one of the mathematical graduates of the University College of Ghana, Legon is dealing with the edge torsional problems which will help to bring the assumptions nearer to the truth.

Solutions were obtained by using a finite difference procedure suggested by the works of JENSEN (1941) of Illinois. The basic equation is expressed as a two dimensional pattern which is moved about a grid representing the finite points on a slab. Special equations were built up to represent the boundary conditions. For example, for the simplest analysis where it is assumed that the slab is hinged at the junction with the beam the slab edge bending moment may be equated to zero and the vertical load of the slab made equal to the vertical edge reaction of the beam. This gives a manageable boundary equation. The results of these operations give a series of simultaneous equations which express the relationship of the deflections of the finite points in the slab. It needs quite a lot of time building up the sets of equations, and in the early years of our efforts some very laborious work was necessary solving simultaneous equations in sets of 9 or 15 unknowns, but now with the aid of the electronic digital computer there is no difficulty in solving some very formidable sets of equations. The computer at my last University could easily handle sets of simultaneous equations with 60 unknowns.

The results of one set of these analytical studies is shown in the diagram. Fig. 4. This shows the distribution of bean reactions, i.e. the effective load per unit length of beam for various values of the ratio of the flexural rigidity of the slab to the flexural rigidity of the beam. The dashed line shows the corresponding value of the effective load recommended by a Code of Practice.

An analysis of any particular slab and beam system by this method would be too complex and time consuming for normal office design. At the same time as Dr. Harrop did this work, Dr. Wood of the Building Research Station was carrying out similar studies and their results were compared.

Dr. Harrop went a step further and investigated the significance of Poisson's ratio which Wood had for convenience assumed to be zero. It had more significance than was expected and could result in a 20 per cent increase on slab bending moments and a decrease in beam bending moments of 4·5 per cent.

The final object of developing simple design rules which could be verified by the more elaborate elastic analyses was pursued by Wood of Building Research Station and he showed that for a square slab (using fairly simple assumptions for edge conditions) the beam bending moment could be expressed by simply

$$M \text{ beam} = \frac{qL^3}{20} \left(\frac{\nu}{(0{\cdot}6+\nu)}\right)$$

when $\nu = \frac{EI}{DL/_2}$ for a single slab, EI is the beam " stiffness " D is the slab " stiffness " and L is the width of the slab. Harrop developed this and discovered a very useful linear relationship between slab bending moment and beam bending moment. This is illustrated by the diagram Fig. 5. From this he extended Wood's formula to give slab moment in terms of beam moment, i.e. centre slab moment.

$$M \text{ slab} = 0{\cdot}1055qL^2 \frac{1{\cdot}35\ M \text{ beam}}{L}$$

at edge of slab

$$M \text{ slab} = 0{\cdot}1583qL^2 \frac{3{\cdot}08\ M \text{ beam}}{L}$$

The results of the application of these equations to beam moments calculated from the elaborate elastic analyses are compared in the following tables.

Values of ν	0·2	0·5	1·0	2·0	6·0
Moment at centre Equation (2) ..	0·0886	0·0749	0·0632	0·0537	0·0441
Finite difference analysis	0·0885	0·0744	0·0625	0·0524	0·0425
Moment at edge Equation (3) ..	0·1198	0·0883	0·0618	0·0398	0·0178
Finite difference analysis	0·1215	0·0898	0·0625	0·0388	0·0154

Comparison of Elastic Analyses with the results of the live Load Test

A rigorous elastic analysis relative to the conditions applying in the field should provide for the membrane stresses the column bending moments and a fairly elaborate definition of the boundary conditions. This is the type of problem that still remains to be solved. Nevertheless a very useful estimate of the effect of combined bending and twisting of the slab and beam can be made assuming that the neutral axis of the slab and beam coincide and that the effective stiffness of the beam is equal to that of the encased section.

The diagram Fig. 6 shows the bending moments calculated by means of the finite difference analyses compared with the observed moments. Also shown are the live load bending moments based on the more usual assumptions of either simply supported slabs and beams or continuous slabs and beams. The agreement is more close to the more exact analyses. The difference between the moments of the two beams is caused by the reduction of continuity resulting from the omission of a floor bay one removed from the bay under test.

Laboratory Tests

At the same time as the field investigations were going on a number of laboratory tests were made. For this purpose electrical resistance gauges were used to measure strains. Such a gauge consists of a grid of parallel wires connected in series and loaded to a thin paper by a special adhesive (Another form is a printed circuit on an araldite backing). The whole assembly is cemented to the test surfaces. The strain suffered by the wire is proportional to the change of resistance but there are creep phenomena which need consideration. Each active gauge on the test member is matched by a similar gauge cemented to a similar unstressed member (Often this is impossible so that what we call the " dummy gauge " or " temperature vompensating gauge " has to be attached to a similar piece of material. It would be a bit difficult to have for example

a duplicate multi-storey structure). The active and dummy gauge form two arms of a Wheatstone bridge. The change of resistance is measured by a galvonometer sensitive to micro-volts using a null-point method on a potentiometer.

All sorts of difficulties arise with these things and we always tend to suspect anybody's results unless we are very certain that they are experts in the use of these gauges.

The two most useful features of laboratory tests compared with field tests are that one can obtain better control of tests conditions and that we can test to the stage of complete failure of the specimen.

A number of tests were made on model slab-beam systems and in the early stages of loading there was a high measure of agreement between calculated strains and deflections and the experimental results. But there are stages between working loads and collapse loads where correlation is difficult because of the various stages of cracking—it should be mentioned that in all normal reinforced-concrete structures there is always cracking in the tension zones. The cracks below the neutral axis are small and are provided for in the design procedures. In prestressed concrete cracking is usually eliminated.

We are also interested in collapse loads. Main cracks develop at predictable fracture lines. A quite different design code can be based on these so called " collapse " or " fracture line " theories. Here one of the difficulties is that collapse also depends on horizontal restraints which are difficult to predetermine in buildings. A test rig has been set up here in the Post-Graduate Research Unit Laboratory (University College of Ghana) which can deal with this problem.

Influence of Investigations on Future Design

It has early been pointed out that the composite action of slabs, beams columns and wall panels can give stresses less than those calculated by commonly accepted design procedures. The problem for the research engineer is the satisfactory explanation of these results, the establishment of improved principles of design and the verification such principles in such a manner that they may be confidently applied to future design.

The work so far has led to certain useful recommendations. In most fields of engineering there will remain problems in which an approach to highly indeterminate conditions will have to be made by considering parts of the structure and making assumptions which simplify the boundary conditions. But there are dangers in a piecemeal approach (Such dangers have, for instance, been demonstrated in connection with the elastic stability of frames). It is much more satisfactory if a general principle of design can be established which takes account of the complicated indeterminate conditions. No doubt modifications will be required to allow for the difference between the idealized and the actual properties of the sections. But, if simple design rules are then developed against the background of the more rigorous solutions the limitations of the approximate methods can be precisely established.

The possibility of developing simple formulae which give results very close to those of the more rigorous elastic analysis has been demonstrated for certain conditions. There is every indication that similar simple rules may be established for more complicated edge conditions. In the meantime analytical studies need to be extended; the numerical work is laborious, but the bulk of it can be done by digital computer.

Both the plastic collapse and the elastic design methods need much more investigation. In either field it is appropriate to quote the remarks of Brennan (1951) who wrote in connection with analytical studies " Even with reasonable conformation between the assumed action and the structural action, mathematical analysis is not sufficient by itself. Testing, experience and judgment must be considered and evaluated with analysis ".

Aknowledgments

The research project was sponsored by the Department of Scientific and Industrial Research and were made possible by their financial assistance. The author wishes to acknowledge his indebtedness to the encouragement of Professor R. H. Evans of Leeds University, England where this work was initiated.

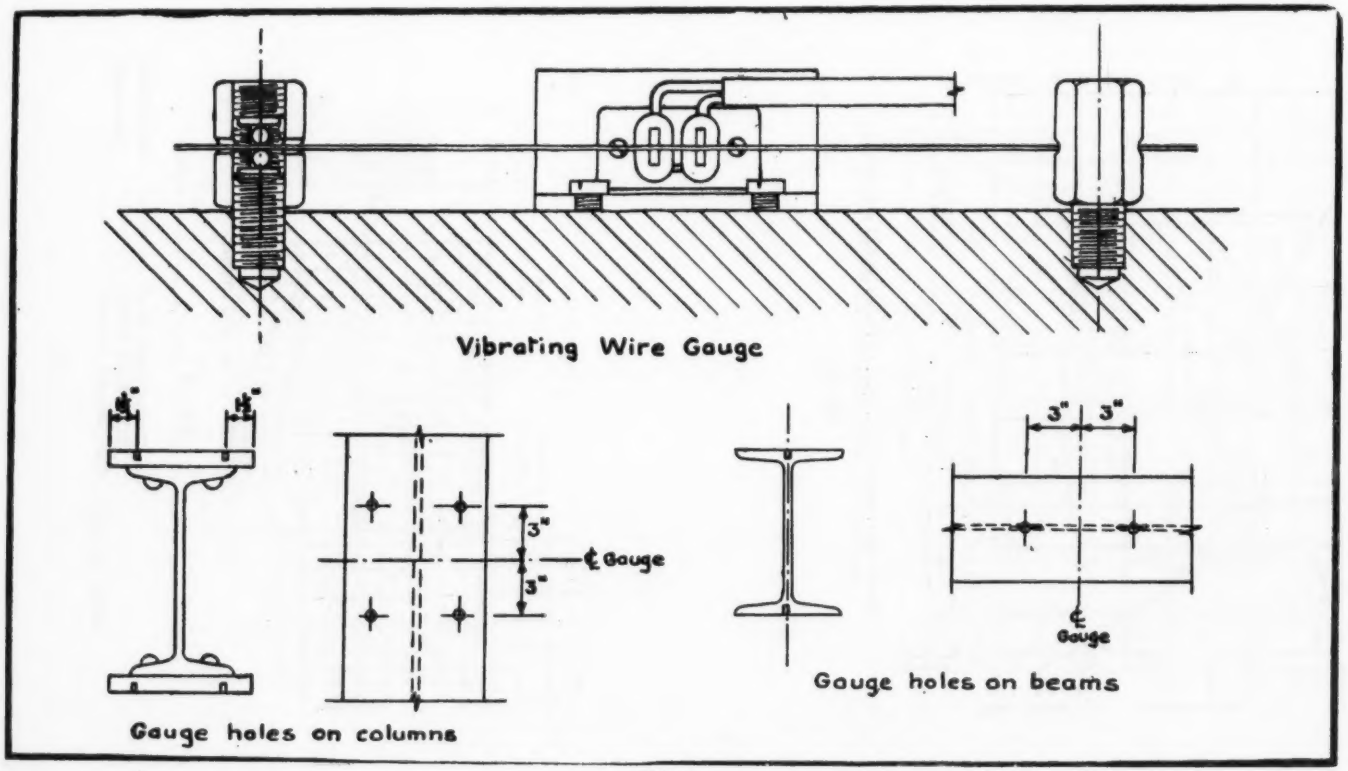
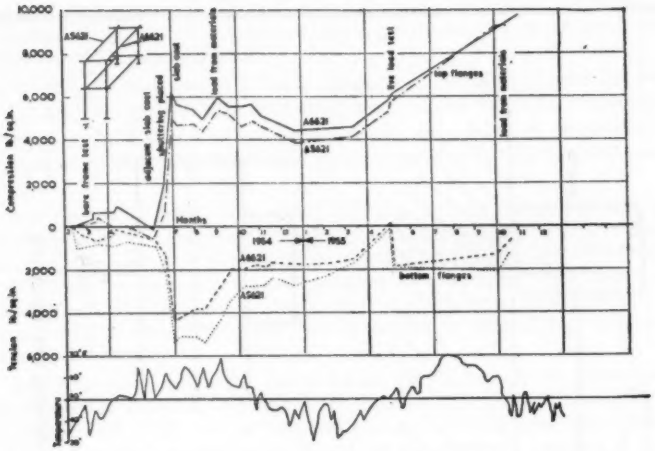
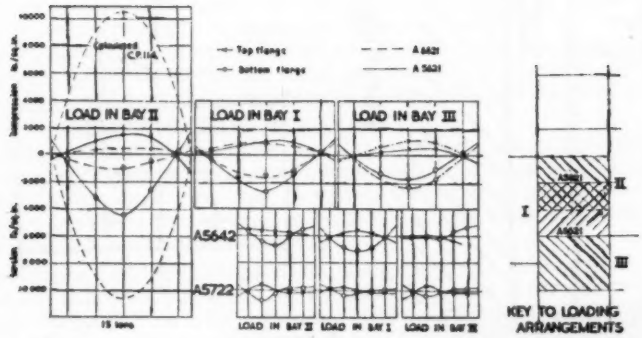

Vibrating Wire Gauge
3"
3"
℄ Gauge
Gauge holes on columns
3"
3"
℄ Gauge
Gauge holes on beams

FIG. 1.



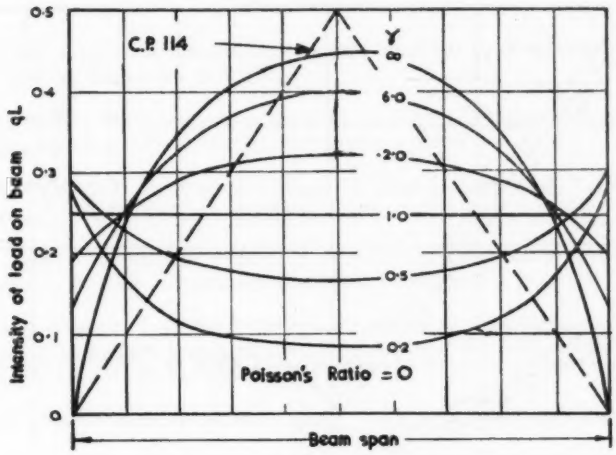
Dead load stresses at mid span of beams A6621 and A5621.

FIG. 2



Distribution of live load stresses.

FIG. 3



Distribution of load intensity of edge beam.

FIG. 4

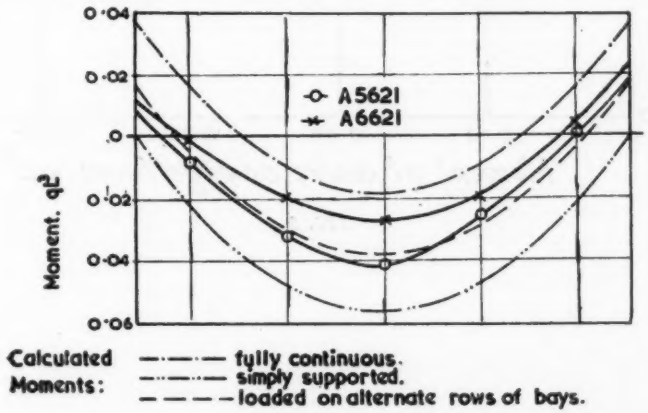


FIG. 6

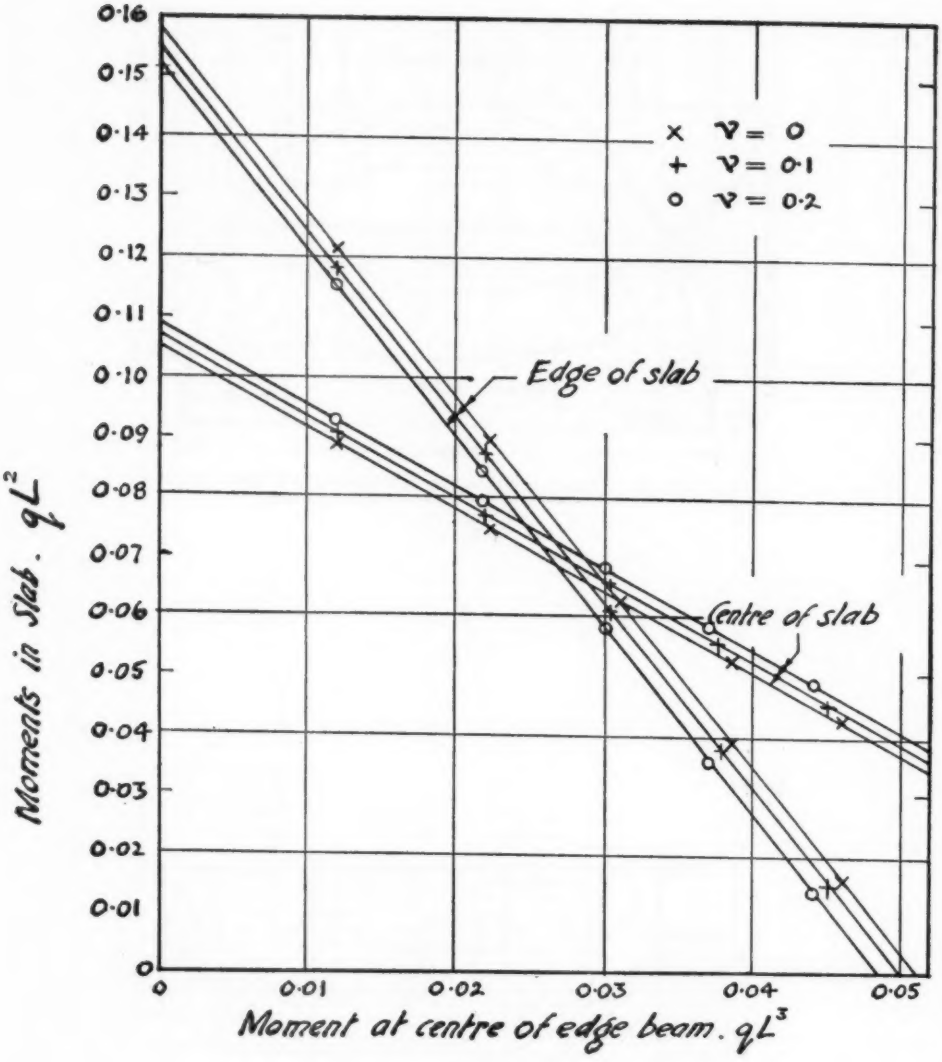

0·16
0·15
0·14
0·13
0·12
0·11
0·10
0·09
0·08
0·07
0·06
0·05
0·04
0·03
0·02
0·01
0
0
0·01
0·02
0·03
0·04
0·05
× ν = 0
+ ν = 0·1
o ν = 0·2
Edge of slab
Centre of slab
Moments in Slab . qL²
Moment at centre of edge beam . qL³

FIG. 5

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SPEECHES AT THE SYMPOSIUM ON "ATOMIC ENERGY" BY MEMBERS OF THE INTERNATIONAL ATOMIC ENERGY AGENCY MISSION AT THE FIRST CONFERENCE OF THE GHANA SCIENCE ASSOCIATION, 1ST APRIL, 1961

1. Mr. J. C. WEBB, *Leader of Mission and nuclear raw materials expert.* "PURPOSE AND ACTIVITIES OF THE AGENCY".

Mr. Chairman, Ladies and Gentlemen,

According to its Charter, the Agency shall seek to accelerate and enlarge the contribution of atomic energy to peace, health and prosperity throughout the world. It shall ensure so far as it is able, that assistance provided by it or at its request or under its supervision or control is not used in such a way as to further military purposes.

The technical operations of the Agency include Reactor studies, Power studies, Reactor research; Supply of Materials, Isotope development, Health and Safety, Scientific Information, Conferences, Legal and Safeguard aspects, and Technical assistance.

The purpose of the Agency in sending out the present mission to different countries in Africa is to make a general survey in the field of atomic energy , to hold discussion with the authorities on the plans, aspirations and other relevant matters relating to atomic energy, to give advise if requested, on the various specialist aspects of the Agency. It is for this purpose that members of the present team are selected for various specializations. The team has an international character in thus considers this point in the treatment of their subjects and discussions. I will now consider a few aspects of the problems of Raw Materials and Power with which the Agency deals.

Nuclear Raw Materials

Atomic energy makes demands on materials previously little known or developed. These may be grouped as follows.

(*a*) *Source Materials.*—U.238 and Thorium.

(*b*) *Fuel Materials.*—The purpose of these is to provide fissionable atoms. The most familiar of these is U.235 which is contained in natural Uranium to the extent of 0·7 per cent.

(*c*) *Breeder Materials.*—There are largely made up of U.233 formed by the neutron bombardment of Thorium (232), and plutonium formed from the neutron bombardment of U.238.

(*d*) *Control Materials.*—The function of these is to absorb the neutrons in a controlled manner to permit adjustment of reactivity. By inserting or withdrawing such materials the reactor can be started up, shut down, or power level changed. Cadmium, boron, hafnium and rare earths which have the necessary qualities of high absorption cross-section.

(*e*) *Moderator Materials.*—These are used to slow down neutrons from the very high energies at which they are born in fission to thermal energies. Such materials must have low atomic weight and low cross-section. Non-metals such as heavy water, graphite and natural water can be used. The main metallic element is beryllium.

(*f*) *Canning Materials.*—These are used to enclose the fuel materials. The materials must not react with the fuel or the moderator must have low neutron cross-section and resistance to distortion at the operating temperature. Some of these materials are Cluminium, Magnesium, Zirconium, Niobium and Beryllium.

Power

Atomic power plays a major part in highly industrialised countries with fuel shortage. The main obstacle at present is the high capital cost. This makes reactors progressively cleared with decreasing size. At present the only reactor of a size that is approaching economic considerations produces 60 to 100 m.w. but the trend is now towards increasingly large reactors of a capacity of 500–1,000 m.v.

Extensive research is under way on the design of small nuclear reactors of about 10 m.w. which would fill a much greater need and be much more flexible in use. This will be particularly valuable for remote areas, distant from grid or areas of small power supply. Research is also being conducted for the production of small gas or metal cooled reactors for use in arid regions. Finally, possibilities of utilizing nuclear energy for large scale production of process-heat for industrial purposes are being investigated.

2. Mr. A. KOZLOV, *Training and Information Expert*.—" TECHNICAL ASPECTS ".

Mr. Chairman, Ladies and Gentlemen,

The International Atomic Energy Agency has from the very beginning of its existence been engaged in training nationals of its Member States. The data available to the Agency indicate that most of the African countries which have recently achieved political independence suffer from an acute shortage of scientifically and technically trained personnel and of modern equipment for the laboratories of their universities, colleges and other educational centres.

Modern achievements of nuclear science have as yet been little used to improve health and well-being. What is more, sufficient technical grounds for such applications of atomic energy seldom exist and there is an urgent and vital need of the African countries for immediate improvement of general education which would greatly improve the character and speed of the development of all branches of their national economy. It must be recognized that training in nuclear science technology is only one aspect of the many grave and pressing problems of economic and social development of most of the countries in the area and that it is essential that any nuclear science programme be integrated in the general development programme.

The Agency's assistance to countries of Africa which recently became independent has many aspects, such as the granting of fellowships and sending of visiting professors. The object of this programme would be to promote the creation of local scientifically and technically trained personnel or specialists well acquainted with the basic principles of nuclear science and its possible applications for peaceful purposes, in accordance with the specific circumstances of each nation and the whole region. The Agency, bearing this in mind, will promote the sending of visiting professors at the request of interested countries and the awarding of fellowships to students from that region. Fellowships could be awarded for short as well as for long periods, i.e. 4 to 6 years, in order to train specialists with a wide knowledge in the field of theoretical and experimental physics in general and theoretical and experimental nuclear physics in particular and also in the field of medical and agricultural sciences including the application of radio-isotopes. During three years, 1958–60 inclusive, the Agency awarded about 1,000 fellowships in different fields of atomic energy. It is recognized that the raising of the standard of overall education is extremely important at the present time. Education in nuclear sciences should nevertheless be parallel. This would allow the build-up of a nucleus of scientists who have an intimate knowledge of local conditions, national customs and traditions of the people and who would gradually take on their own shoulders the burden from the scientists from abroad. Moreover, training of specialists and the teaching staff for higher educational institutions from among the nationals could create the conditions necessary for further development of these institutions and scientific centres. This can only be obtained by developing a real scientific tradition in the country. Clearly the university must play a major part in developing this tradition. The feeling appears to be that the quality of teaching, using the word in its broadest sense, at all levels is of primary importance within a university. This cannot be maintained at the higher levels unless it is accompanied by research carried out at the university.

The Agency helps the countries in scientific planning in the enlargement of curricula of higher educational institutions bearing in mind national conditions of each country. The Agency can organise a mobile or transportable exhibition on the peaceful uses of atomic energy in order to raise interest in nuclear science and its application for peaceful purposes among intellectuals and students of all ages.

The Statute of the International Atomic Energy Agency provides that each Member State should make available such information as would, in the judgement of the Member, be helpful to the Agency. The Agency has assembled, will continue to assemble, and make available in

an accessible form the information thus made available to it. Further, the Agency has taken positive steps to encourage the exchange of information among its Members relating to the peaceful uses of atomic energy.

The facilities and services of the Agency have now been organised to such an extent that it is possible to offer them to Member States, and to scientists working in national institutions concerned with the peaceful applications of atomic energy. The services are: Library service, responsive information service, dissemination of information, compilation, preparation and publication of scientific and technical reports, and the organization of conferences.

I want to thank you for having listened to me and I wish the people of Ghana success in the development of industry and the training of national scientists, professors, engineers, agronomists and other specialists for the prosperity of the country.

3. DR. H. T. EL-DAW, *Medical Radioisotope Expert* " NUCLEAR ENERGY IN MEDICINE ".

Mr. Chairman, Ladies and Gentlemen,

The physician was among the first to recognize the value and great usefulness of radioactive isotopes in research, diagnosis and treatment.

Before the availability of man-made radioactive materials, natural radioactive isotopes were used in various medical applications, to mention as example radium and radon seeds used by man in the combat of cancer.

With the availability of the artificially produced isotopes in large quantities it can be safely said that the medical profession and investigators in medical science have been responsible for a large portion of the uses. Applications have spread from the large medical centres to the smaller hospitals and in some countries even to private physician offices.

I wish to summarise briefly the medical uses of atomic energy.

First of all the diagnostic applications of radioisotopes which can now be considered of routine applicability include the following:

(*a*) Evaluation of thyroid function using radioactive iodine. This is the most widely used clinical application of radioisotopes. This test is based upon the well-established relation between the avidity of the thyroid gland for iodine and its functional state. The rate at which the thyroid gland accumulates radioiodine from an orally administered dose and also secretes labelled hormone into the blood stream are useful indexes of its function.

(*b*) Blood and plasma volume measurements using radioiodinated serum albumin are based on the dilution which takes place when the radioactive material is introduced into and becomes mixed with the total circulating blood.

(*c*) Measurement of red cell mass and red cell survival using radioactive chromate: this method depends on the fact that viable red cells when incubated in a test tube with Cr-51 labelled sodium chromate the cells bind the Cr-51 making it possible to trace the cells in the body upon reinjection.

(*d*) Studies on the absorption of cobalt labelled vitamin B-12 in the diagnosis of pernicious anaemia. This method makes use of the absorption of vitamin B-12 from the gastro-intestinal tract in the presence of an intrinsic factor elaborated by the gastric mucosa. The absorption may be followed after the oral administration of radio-cobalt labelled vitamin by estimation of the unabsorbed radioactivity in the faeces by measuring the radioactivity in the liver which acts as a temporary storage site after absorption or if the liver uptake is blocked by parentral administration of a large dose of unlabelled vitamin B-12 and collecting the using for 24 hours and examining for the excreted labelled vitamin B-12.

(*e*) Evaluation of kidney function test with radio-iodine labelled dyes. The labelling with radioactive iodine of substances cleared by the kidneys has permitted the evaluation of the function of these organs by external counting with probe scintil-

lation detector. Inspection of the pattern of recorded curves of radioactivity over each kidney has given information about the vascularity, parenchymal function and patency of excretary ducts.

(*f*) Studies on the digestion and absorption of fat using radioiodine labelled triolein and oleic acid.

The labelled triolein is administered on a capsule or emulsion in milk and its appearance in the blood stream followed by making counts of the blood at intervals after ingestion of the fat. If the amount which appears in the blood stream is low, labelled oleic acid can be used to differentiate between lack of digestion and poor absorption.

These clinical examples constitute by far the greatest number of applications of radioisotopes in medicine.

Recently, it was made possible through the use of needle probe scintillation counters by neurosurgeons to locate and determine the extent of brain tumors at surgery. Also, the small probe counters have found use in helping the surgeon to locate active thyroid tissue in the neck at surgery for thyroid carcinoma. The small detector has also found use in the identification of intra-ocular lesions. The probe can also be used in estimating the radiation doses delivered to organs such as the rectum or uterus for radioisotopes used for tumor therapy.

The second medical applications would be the therapeutic applications. Here the field is limited; a radical cure can be effected for selected cases of thyratoxiconis by radioiodine. Cancer of the thyroid is promising even in what was considered before late cases by the appearance of secondries in the lump. P-32 can be of curative value in the rare disease of palycythaemia vera. However, radioisotopes have their place in cancer. Colloidal gold can be used as palliative to prevent malignant exudation in serum cavities. In addition surface applicators containing radioisotopes are used to treat certain skin and eye conditions. Sealed sources containing radioactive isotopes such as Co are used to treat various types of malignant deep seated tumors where by a maximum energy can be delivered to the tumor-tissue with a minimum damage to tissues inbetween.

A third application is in the biochemical research where through the labelling with—as an example—carbon-14 the metabolism of many organic metabolites could be traced and their intermediate steps determined. The future trends in biological research may go along the above lines mentioned, and in addition there is the possibility of locating the biologically active bond in a biological molecule through the incorporation of a radioactive atom at the location under study and through the recoil energy of disintegration rapturing their specific bond could be effected.

Lastly, comes the question of the safe handling, storage, transportation, etc., of radio-isotopes. For this purpose, various international recommendations are available and it can be said that in general the requirements for the use of tracer doses in well-established diagnostic procedures are less stringent than those for therapeutic application or non-routine uses.

4. M. S. BOUYER, *Agricultural radioisotope Expert* " NUCLEAR ENERGY IN AGRICULTURE ".

L'emploi des radio-isotopes constitue une methode moderne et elegante d'investigation dans tous les domaines de la recherche agronomique: science du sol, production vegetale, production animale, lutte contre les ennemis des plantes et des animaux, conservation des produits agricole.

Dans le domaine de la science du sol, les radioisotopes se revelent utiles pour l'etude de la fertilite naturelle des sols d'une part et dans l'amelioration de cette fertilite par les engrais d'autre part. La fertilite est la resultante complexe de nombreux facteurs dont les principaux sont l'eau, les facteurs physiques, les elements chimiques nutritifs; la sonde a neutrons est appelee a rendre de grands services partout ou l'eau est un facteur limitant de la croissance des plantes; elle permet de preciser la capacite de retention de l'eau d'un sol et d'orienter les programmes d'irrigation. La technique d'echange isotopique, d'autre part, semble enfin donner

une solution rationnele au probleme si controverse des elements chimiques assimilables, c'est-a-dire de la fraction de ces elements que la plante peut utiliser; cette technique a deja fait l'objet de nombreuses etudes dans le cas du phosphore et elle serait specialement utile pour les sols tropicaux dans lesquels, on le sait, le probleme se presente sous un aspect tout particulier; les dernieres conclusions insistent sur le fait que le phosphore isotopiquement echangeable et la concentration de cet element dans les solutions du sol doivent agir de facon concommitante sur la croissance des plantes et les rendements; mais le probleme est loin d'etre completement elucide et de nombreuses etudes sont encore necessaires; des recherches similaires peuvent etre faites pour le calcium, le potassium, le soufre et les oligoelements; pour l'azote, on ne dispose pas d'isotope radioactif a periode suffisamment longue et l'on utilise l'isotope stable ^{15}N, dont la determination doit etre effectuee au spectrometre de masse; enfin, le ^{14}C permet l'etude de la matiere organique qui est d' importance capitale. L'emploi rationnel des engrais a fait de grands progress, tant en ce qui concerne leur coefficient d'utilisation que leur mode de placement, grace a l'emploi des radioisotopes; c'est ainsi que dans certains cas on a pu montrer que la fumure foliaire est la technique la plus economique; tout est a faire encore dans ce domaine pour les cultures tropicales.

En physiologie vegetale, le mecanisme de la photo-synthese a pu etre precise grace au ^{14}C; on a montre aussi que le systeme radiculaire possede en realite une fonction synthetique de certains constituants de la plante, fonction que l'on ignorait jusqu'a ce jour; on a egalement mis en evidence un lessivage du feuillage des plantes par les pluies et une excretion de certains elements par les racines; l'action des hormones et des regulateurs de croissance a pu etre precisee, de meme que la synthese de certains constituants et leur circulation dans la plante. Une autre aspect important de la production vegetale, l'obtention de nouvelles varietes a fort rendement ou douees de proprietes interessantes telles que la resistance aux maladies, semble appele a connitre une veritable revolution par l'emploi des radiations ionisantes; l'irradiation de semences ou de boutures accroit considerablement les mutations qui peuvent se produire naturellement; un tres petit nombre seulement de ces mutations peuvent etre interessantes, mais avec un peu de chance ou par un travail de selection tres soigne on peut arriver a les deceler.

C'est surtout dans les recherches physiologiques que les radioisotopes peuvent rendre des services dans le domaine de la production animale: croissance, formation du squelette, production lactee, production des oeufs, de laine, localisation des tumeurs; leur emploi est d'autant plus interessant que souvent l'etude peut etre faite sans que l'on ait a sacrifier l'animal.

Dans la lutte contre les ennemis des cultures, on peut utiliser soit la methode d'irradiation qui permet de steriliser certains insectes et de provoquer ainsi leur disparition, soit la methode des radiotraceurs qui permet d'etudier la biologie des insectes, de suivre l'evolution des insecticides dans les plantes et de deceler eventuellement leur presence dans les produits alimentaires qu'elles fourmissent.

Enfin, il est possible que la conservation des denrees alimentaires d'origine vegetale ou animale fasse de grands progres grace aux techniques d'irradiation; mais, dans ce cas, il faut se montrer tres prudent.

Un expose de quelques minutes, relatif aux applications des radio-elements en agriculture, est obligatoirement tres incomplet; les quelques exemples precedents demontrent cependant amplement les immenses possibilites qu'elles permettent d'envisager et ils expliquent l'interet considerable suscite actuellement dans le monde agronomique.

RADIO-ISOTOPE UNIT*

by DR. A. H. WARD

Senior Lecturer, Department of Physics, University of Ghana

Introduction

Radioisotopes can be of value in so many different ways. It is easy to demonstrate with a portable radioactivity meter the sort of radiations we are dealing with, that is with parts of tree labelled with radioisotopes emitting beta and gamma radiations, separate detection of these, and penetrating power of the radiations.

The main uses and advantages of radioisotopes may be summarised as follows: When a material is " labelled " with a radioactive form of one of the atoms of the constituent elements, the radioactive " label " moves with the material in every respect and so may be used as a " tracer " for the material. This can be illustrated by means of radiotracer investigations in Ghana. The radiotracer method is usually more sensitive than conventional methods, and can often be non-destructive, as the radiations can penetrate through considerable thicknesses of tissue or other solid from the labelled material inside to the radioactivity detector outside. In many biological experiments, this non-destructive approach allows good accuracy to be obtained with fewer replicates; in some medical and industrial work, it allows otherwise impossible problems to be tackled. In nearly all cases results can be obtained more quickly by radioisotopes than by other means.

There are disadvantages, however. The chief one in Ghana is the need of specialised and delicate radioactivity measuring equipment, but there is always in addition the danger to health of misuse of or mistakes with radioactive materials. I would like to recommend the newly-published booklet " Code of Practice for the Protection of persons exposed to ionising radiations in Universities of the British Commonwealth "; this book will be extremely helpful in the medium-scale radioisotope work which will be needed in Ghana.

Applications of Radioisotopes in Ghana

Already there have been several projects involving radioisotopes in Ghana, and I would like to discuss some of these, although my own share in some cases was limited to advise on the application, detection and interpretation of radioisotopes as a tool for another scientist's problems.

This is so in the co-operation with W.A.C.R.I., where a small 2-room radioisotope laboratory was built in 1953. One of the early experiments there involved the labelling of mealy-bugs with radioactive phosphorous (P32) to trace their distance and speed of migration under natural conditions. Another experiment was on the uptake by cocoa trees of phosphate fertiliser labelled with P32 at various seasons after different soil, root and trunk applications. An experiment in progress at W.A.C.R.I. at present involves a systematic insecticide labelled again with P32; the speed, spread and breakdown of the insecticide in cocoa trees is being investigated, the radioactivity being counted both from the standing cocoa trees using portable instruments and from samples brought into the laboratory and chemically treated.

In the Faculty of Agriculture at Legon, somewhat similar investigations were performed on the uptake of available and " unavailable " phosphates from different Ghana soils by several crops of economic importance; this again involved radiophosphorous P32, as did their investigation of the depth and radial-spread of root feeding at different times from these crops. Studies of phosphate availability in soils using P32 will start at Kwadaso when their new radioactivity laboratories are completed.

An investigation of the toxicity of one of the most hazardous of all radioisotopes—radio-strontium Sr 90—Y90 was completed most successfully a few years ago by co-operation between Pathology, Physics and Zoology specialists. Local species of monkeys were used. Two of the

*A talk given at the First Conference of the Ghana Science Association, 1961.

significant discoveries were that Sr 90 is relatively more toxic in monkeys than in smaller animals, and that the simple blood count often stayed within the normal range for many weeks after an injection of radiostrontium which eventually proved lethal (in contrast to the widely accepted view of the role of blood counts in the early detection of radiation damage).

The other " biological " applications of radioisotopes are continuing. The Pharmacy Department (Kumasi College of Technology) includes radio-iodine, radio-gold, etc., in their instruction courses, and have built and equipped a " warm-lab ". Here at the University College, there is a bio-chemical investigation into production of pteridine from folic acid labelled with radio-carbon and tritium (radioactive hydrogen).

Another research project in the Chemistry Department of the University College involves two simultaneous radio-tracers—K 42 and Ca 45 for measuring ion-exchange capacity in clays.

For 18 months the radioactivity laboratory in the Physics Department at Legon has been largely concerned with " natural " and " fall-out " levels of radioactivity in samples of food, water, soil and air. It is a pleasure to acknowledge the excellent co-operation of the Department of Meteorology and Ministry of Agriculture in choosing, collecting and sending these samples to us; and it is interesting that the wind charts of the Department of Meteorology for the days after French atomic tests at Reggan fit in well with the observed arrival of fall out, especially after the test of 13th February, 1960 when radioactivity levels rose considerably in many areas of Ghana.

Finally, I would like to mention the expansion of radioisotope work now envisaged. The National Research Council is financing the " Health Physics and Radioisotope Unit " to extend the co-operation with Agriculture, Medical Research and Hospitals, Department of Public Construction, industries, Geological Survey and Ministry of Defence, in introducing radioisotope techniques where these will be most useful. It is to be sited at the Physics Department, Legon, and will consist of three main parts, a " warm " laboratory for handling safely medium quantities of radioisotopes, a " low-level " counting laboratory equipped with specially sensitive detecting equipment, and a set of portable equipment together with suitably trained radioisotope technicians, for " loan " to other Department and Institutions.

GEOLOGICAL AND ARCHAEOLOGICAL EVIDENCE FOR THE LATE QUATERNARY CLIMATIC SEQUENCE IN WEST AFRICA*

by DR. O. DAVIES

Reader in Archaeology, University of Ghana, Legon

I have limited this paper to the Late Quaternary, because in West Africa Early and Middle Quaternary formations are very scarce, and in general little is known about them. From the few fragments of beaches and river-terraces no coherent climatic picture can be elicited, and the extensive coastal formations, like the Niger delta or the Togo " terres de barre ", have not been properly examined or have not been published. Moreover, I have generally used as zone-fossils human artefacts, the only remains normally available in West Africa; and before the Late Acheulian and Sangoan industries of the beginning of the Late Quaternary, the human sequence is disjointed and fragmentary.

I propose to pursue two lines of enquiry, river-terraces and soil-sections with the phases of cementation they have undergone; and I wish to shew that these two lines provide a co-ordinated picture of climatic fluctuations, which can be tied to a chronological scheme. For reference I start with a chronological table:

Climatic stage	*Approximate date B.C.*	*Equivalents in Europe, and where relevant in other parts of Africa*
Sub-pluvial III and recent	900–	Sub-Atlantic; ? Nakuran (E. Afr.).
Post-pluvial III	1300–900(1)	Later Sub-boreal.
Sub-pluvial II	5500–(2800) 1300	Atlantic; ? Makalian (E. Afr.).
Post-pluvial II(2)	? 8000–5500	Pre-Boreal, Boreal; ? Allerod.
Sub-pluvial I(2)	? 10300 or 8800–8000	Older and/or Younger Dryas.
Post-pluvial I	? 25000(3)–10300 or 8800	Hauptwurm-Spatwurm, ? Allerod.
Gamblian	40000+ – ? 25000	Gottweig + Hauptwurm.
Pre-Gamblian aridity	Between 70000 and 40000	Between Beaches IV and V(4).
Kamasian	Before 70000	In East Africa the later part is called Kanjeran.

NOTES TO TABLE

The nomenclature for the holocene is from Butzer, *Quaternary Stratigraphy and Climate in the Near East* (Bonner geographische Abhandlungen 24). His scheme was drawn up for the Near East and North-east Africa, and the dates are based on radiocarbon-dates for that region; it seems to work pretty well for West Africa north of the equator. The nomenclature for the Late Pleistocene is from Leakey and others, without assuming close equivalence between West and East Africa.

(1) The aridity of Post-pluvial III started well before 1300 B.C., probably about 2800 B.C.; but it reached its peak about 1300.

(2) These phases hardly exist in West Africa; *see* below on Nalori.

(3) The date 25000 for the beginning of Post-pluvial I is dubious. It is based on a radiocarbon-date for the beginning of frost-weathering at Haua Fteah cave, Cyrenaica, which fits with the date of the Paudorf interstadial, when conditions in the European periglacial area became very dry; but Post-pluvial I will then be surprisingly long.

(4) Beach V (= Zeuner's Monastirian II) must, on the radiocarbon-dates for Kalambo Falls (N.Rhodesia) be the equivalent of the Gottweig interstadial; I intend to argue this disputed point at the International Quaternary Association in 1961. Beach IV is the equivalent of the Eem interglacial, whose end must be about 70000, seeing that the Amersfoort interstadial dates 64000, and there does not seem to be a long interval between this and Late Eem. Evidence particularly from South Africa enables us to place the arid period between the two eustatic high-level beaches.

River-Terraces

Three river-terraces with gravels can be distinguished in West Africa in the zone between the coast and the peneplain; but of the High (about +30–35m.) and Middle Terraces (about +25m.), which respectively carry pre-Chellean and Late Chellean artefacts, only fragments

*A paper read at the First Conference of the Ghana Science Association, April, 1961.

remain, on the Birim Ofin Ankobra and elsewhere. The Low Terrace, at about +10m., rising to +14m. near the mouths where it grades to Beach IV, carries unrolled Sangoan tools and sometimes rolled Late Acheulian and older industries.

The river-terraces are old valley-bottoms, and the artefacts in their gravels can be dated with some precision in relation to the terrace-cycle. The gravels have hardly been affected by subsequent scarp-retreat, which may have left talus at the foot of the valley-sides but would not attack the nearly level bottoms. Thus slope-gravels may be much younger and contain younger artefacts than terrace-gravels. The terrace-cycle in the woodlands and forests of West Africa is as follows:

Incision, leaving perched the last terrace and its gravel	Beginning of pluvial, when there is still little protection by vegetation.
Formation of rejuvenated valley, with large gravel in the bottom.	Pluvial, during which artefacts in the gravel are rolled. Unrolled artefacts must belong to the end of the pluvial, when there was no longer current to work the gravel.
Aggradation of finer sands, sealing gravel and artefacts, rolled and unrolled.	Early interpluvial.
Probable partial erosion of sands; slight further rolling of underlying gravel.	Interpluvial with storms.
Most finer sands are eroded after the rejuvenation, in the succeeding cycle, when the gravels are perched and can no longer be rolled.	—

Thus the unrolled Sangoan tools in the Low Terrace belong to the early and middle part of the pre-Gamblian interpluvial, and the rolled Late Acheulian pieces are not later than the very beginning of the interpluvial.

The valleys incised in the Gamblian pluvial were much wider than the present rivers, and since the end of the pluvial the sequence of deposits has been as follows. It is to be found on every river in Northern Ghana; and there is evidence at a few exposures in the south, for instance at Bopa on the Tano, to prove it in the forest-zone.

Sub-pluvial III	Under 1 m.	Modern soils, silts perhaps brought up by termites. Near the modern bank erosion of the inner silt-terrace and subsequent aggradation of an outer sand-terrace with turf-lines, indicating probably slight increase and then fluctuating decrease of rain.
Post-pluvial III		Unconformity. Underlying silts mottled or formation of pisoliths. On the unconformity-surface mesolithic.
Sub-pluvial II	5–6 m.	Deposition of sands and above them of white silts. Pluvia period with steady rain and formation of swamps, blocking old river-courses. Similar conditions pervailed as far north as the southern Sahara.
	Hiatus	(Below).
Post-pluvial I	50 cms.	Sands and grits usually ferruginised. Middle stone-age unrolled on the underlying basal gravels, perhaps often derived from the sands by erosion.
Gamblian and End-Gamblian		Basal gravels, being the continuation into the bottoms of valley-side rubbles, rolled until the beginning of Post-pluvial I, and containing rolled middle stone-age pieces similar to the unrolled which can be only slightly later. Found particularly at rapids which have cut back, leaving the old lips perched and easy to see.

Butzer could not find the fluctuation Post-pluvial I—Sub-pluvial II south of 30° N, and considered it to be associated with one of the fluctuations of glacial retreat, either Bölling or Alleröd. Radiocarbon-dates and vegetation-studies in north-west Africa indicate that Post-pluvial II was weak, so that Sub-pluvial I and II tend to coalesce. A section recently discovered in the White Volta valley at Nalori suggest that there were traces of this fluctuation as far south as 10° N; but it must be emphasised that interpretation is tentative until radiocarbon and botanical studies can be undertaken at this site:

		Suggested climatic interpretation
7–8 m.	White silts, overlying current-bedded sands.	Sub-pluvial II; high river.
½ m.	Laminated muds, pool-deposits and soil.	Post-pluvial II; very low river.
	Current-bedded sands, up to ½ m. above modern L.W.	Sub-pluvial I; higher river.
	Basal gravels not exposed	Post-pluvial I.

Post-pluvial I was severe in West Africa, and probably throughout the Sahara and in North Africa. The half-continent was practically abandoned by man. South of the equator this phase was much weaker, and almost unnoticeable in South Africa.

Soils

Practically nowhere in Africa are soil-remains older than the pre-Gamblian interpluvial. There is a little evidence for pre-Gamblian lateritisation, especially derived fragments of laterite in Gamblian deposits; and at the foot of an Inselberg one may rarely find a cemented pre-Gamblian soil. For instance, above the Geography Department at Legon a Sangoan pick appeared at 90 cms. depth, well above the base of the block-laterite. I am inclined to think that in the Late Kamasian cycle there was little cementation at the end of the pluvial; for Beach IV at Accra, Bishop's School, must, according to known fluctuations of sea-level, have been deposited and abandoned before the pre-Gamblian interpluvial; yet in the sands were middle stone-age artefacts, so they cannot have been cemented until Post-pluvial I.

The soil build-up in West Africa starts with the lower stone-line, larger pieces which resisted erosion in a dry period when finer material round them was washed away. The stone-line usually rests on rock (often rotten but in situ), it may sometimes be a river-gravel. It normally carries Sangoan tools; any older artefacts are heavily weathered. In the coastal savannah the lower stone-line is sometimes absent, and the oldest layer is the upper stone-line.

The cycle varies slightly according to latitude. (A) In the northern savannah:

Average thicknesses		*Climatic stages*
	Erosion, probably due to human activities	Modern.
50 cms. ..	Soil-accumulation; in the soil neolithic and early iron-age	Sub-pluvial III.
	Erosion of uncemented older soil and traces of stone-line, usually marked only by a few artefacts. Mesolithic.	Post-pluvial III.
	Pisoliths forming below a certain depth in soil; north of 10° N the pisoliths are often cemented. Probable cementation of the older pisoliths formed in Gamblian soil.	End Sub-pluvial II; sharp seasonal contracts.
20 cms. ..	Build-up of soil	Sub-pluvial II.
	Erosion of uncemented Gamblian soil. Formation of upper stone-line from rock-waste in Gamblian soil and from middle stone-age artefacts dropped on the eroding surface.	Post-pluvial I.

1 m.	Build-up of soil	Gamblian.
	Lower stone-line, composed of older rock-waste in previous soil which was otherwise eroded, and probably fresh rock-waste during the arid period; also of Sangoan implements dropped.	Pre-Gamblian.
	Rock, usually altered.	

(*B*) In the forest (except the wettest areas which may have been continuously forest in the driest periods), and where the rock contains refractory material like quartz but little iron for cementation, the cycle is:

Accumulation of earth with a few stones. Neolithic and iron-age		Sub-pluvial III and modern.
Erosion of older earth, leaving rubble, hardly cemented. Mesolithic		Post-pluvial III.
Rubble with some earth	These four levels can often be distinguished only by position of artefacts.	Sub-pluvial II.
Erosion of older earth; middle stone-age		Post-pluvial I.
Rubble with some earth, hardly cemented		Gamblian.
Sangoan artefacts		Pre-Gamblian.
Rock		

In favourable circumstances the upper mixed earth and rubble can be distinguished from the lower, for instance in a section at Tokuse:

15–60 cms. ..	Sand, with white pisoliths near base	—
	Microliths	Post-pluvial III.
8–30 cms.	Illuvial grit with rolled lateritic nodules	Sub-pluvial II.
	Middle stone-age	Post-pluvial I.
5–60 cms.	Irregular rubble	Gamblian.
	Sangoan, found unstratified in the pit, probably came from this level.	
	Rock.	

(*C*) At the foot of the Togo quartzite ranges there are deep sands but no cementation, perhaps because the sands are too porous to permit the fluctuating water-tables on which deposition of iron-salts depends. Sections were drawn in excavations at New Todzi and Legon Botanic Gardens, and in a deep pit at Somanya. As the Legon section has been summarily published (*Antiquity* 33 (1959), p. 290), I give the other two:

NEW TODZI (south Togoland), in an old gulley.

	Red sandy earth	Neolithic near surface ..	Sub-pluvial III.
	Red sandy earth	Two zones of M.S.A. lower down.	Sub-pluvial II and Post-pluvial I.
	Line of lateritic nodules ..		Post-pluvial I.
140 cms. ..	Red sandy earth	Sterile	Gamblian.
50 cms. ..	Rock-rubble on base of gulley	Sterile	? Pre-Gamblian.

SOMANYA, on the Akuse road, ½ mile from the town-centre.

15 cms. ..	Soil	Recent objects.	
50–60 cms. ..	Red sand	Kintampo-neolithic	Sub-pluvial III and II, without unconformity.
	Gulleying of clays	Middle stone-age	Post-pluvial I.
70–100 cms. ..	Clay with nodular laterite ..		Gamblian.
	Rotten quartzite	Probably Sangoan level ..	Pre-Gamblian.

BRÜCKNER put forward a theory of lateritisation-cycles due to climatic fluctuations (*Geologische Rundschau* 43 (1955), p. 307). He did not distinguish the sequences ta different latitudes or according to the composition of the bed-rock, and he telescoped my sequence B, because he failed to notice the middle stone-age artefacts which frequently mark what elsewhere would be the upper stone-line. Moreover, his climatic descriptions may be exaggerated. One may hesitate to speak of " desert-pavements " in West Africa, where there is no evidence for blown sand south of 13° N save locally, for instance in river-beds. It would seem that in dry periods erosion took place between clumps of vegetation and not on bare surfaces, and that rainfall either diminished or became badly distributed, but did not fail altogether. In place therefore of Brückner's cycle " arid—warm humid—semi-arid ", I would prefer to use " dry-warm humid—seasonally contrasting ".

A art however from these criticisms, wide-spread use of artefacts as zone-fossils shews that Brückner's chronology is untenable. I take no account of his suggested equivalences with glaciations and his absolute dates, which were at least speculative. It appears that he himself was surprised at the rapidity of the lateritisation-cycles; yet in fact they have been far more rapid than he himself believed. In the following table I give his dates alongside mine:

	Stage	*Bruckner*	*Date from zone-fossils*
9	Sandy top-layer	Presumably the whole holocene	Sub-pluvial III.
	[Unconformity]		Post-pluvial III (mesolithic).
8	Upper loamy sand with pisoliths	Gamblian	Sub-pluvial II.
7	Upper stone-layer, unconsolidated	Kamasian-Gamblian peak ..	Post-pluvial (M.S.A.).
6	Limonitic crust (i.e. cemented block-laterite).	Early Kamasian-Gamblian ..	Gamblian, soil cemented and partly eroded.
5	Lower stone-layer		Pre-Gamblian (Sangoan).
4	Lower loamy sand	Kamasian	—
3	Breccia	pre-Kamasian	Pre-Gamblian.
1–2	Reconstruction of older cycle from fragmentary remains.		

NOTE TO TABLE

I have never seen stage 4, and Brückner says that 3 and 5 usually merge, and I think normally form a single stage, which may incorporate older elements. If stage 4 is anywhere extant, it supports the view that I put forward above that there was no cementation at the end of the Kamasian cycle, in contrast to the two subsequent cycles

ABSTRACTS OF SOME OF THE PAPERS READ AT THE FIRST CONFERENCE OF THE GHANA SCIENCE ASSOCIATION

1. *Radio Research in Ghana.*—Rev. Dr. J. R. Koster, Department of Physics, University of Ghana.

Recent research in Ghana and elsewhere has discovered some unusual equatorial radio propagation problems. The present state of our knowledge of these is reviewed, and some possible solutions for the practical problems of television and radio broadcasting are discussed.

2. *Structure of the Earth's Crust—an Example from Norway.*—Dr. B. J. Walton, Department of Geology, University of Ghana.

The area described lies close to the Norwegian coast, immediately north of the Arctic Circle. It is a mountainous, well-exposed region in which the structures produced by the Caledonian orogeny can be clearly analysed. These structures include major, recumbent, isoclinal overfolds which have resulted in the inversion of large sections of strata. Minor folds are very abundant and varied in style. Two main phases of folding can be recognised, and the rocks have suffered high grade regional metamorphism and some granitization.

3. *Investigations on some Ghanaian Plant Polysaccharides.*—Dr. F. Torto, Senior Lecturer, Department of Chemistry, University of Ghana.

The plant gums and mucilages are closely related heteropolysaccharides elaborated by certain botanical species. An important feature of the study of the structures of these very complex substances is the isolation and structural elucidation of oligosaccharides produced during partial hydrolysis of the polysaccharides. Two such oligosaccharides, aldobiuronic acids, have been isolated from *Fagara xanthoxyloides* gum and *Afraegle paniculata* mucilage, and their structures determined by methylation, hydrolysis of the fully methylated materials, and isolation and identification of the products.

4. *A Seismic Investigation of the Depth of Bedrock under the Volta River at Tefle.*—F. W. Hales, Senior Geophysicist, Geological Survey Department.

A small-scale seismic survey was carried out to augment depth-to-bedrock data obtained by diamond drilling at the site of the proposed bridge across the Volta river at Tefle. The refraction method was employed. The seismic instrumentation used is described and interpretational aspects of the problem are discussed. The results obtained show good agreement with the data supplied by drilling.

5. *Seas and Oceans.*—Professor W. J. McCallien, Department of Geology, University of Ghana.

Reference is made to the importance of recent ocenographic studies to geological problems. In the past decade such studies have been concerned with the topographic, structural and sedimentary histories of the ocean floors. Some of the conclusions arrived at, mainly in connection with certain aspects of the structure of the earth's crust and with the sedimentary history of the ocean floor, are illustrated. Special emphasis is given to the conclusions drawn from the topographic features of the Atlantic Ocean.

6. *The Correlation of Field, Laboratory and Analytical Studies of Engineering Structures.*—Professor Royston Jones, Department of Engineering, University of Ghana.

It is well known that the complicated inter-action of the various elements of a structure can result in stresses less than those calculated by commonly accepted design methods. The problems of the research engineer are: the satisfactory explanation of these results, a reassessment of the validity of the usual design assumptions, the establishment of improved principles of design and the verification of such principles in such a manner that they may be confidently applied. This paper gives an account of the study of such problems involving field tests, laboratory tests and analytical studies which took advantage of the facilities provided by electronic digital

computers. Incidentally it outlines some of the special difficulties which arise in developing sufficiently robust and reliable strain measuring techniques for field measurements.

7. *The Effect of Induced Environmental Changes on Insect Populations in Cocoa.*—Mr. E. Dunn, Head of Entomology Division, W.A.C.R.I., Tafo.

The use of insecticides to control the capsid, one of the major pests of cocoa, has been outstandingly successful, but it has been found that the introduction of insecticides may result in the increase of a minor pest or perhaps the appearance of a new pest. Attempts to control mealybugs by the eradication of the ant with insecticides caused the appearance of new pests. The reduction of shade has greatly increased yields but at the same time this has brought about an increase in certain insect pests.

8. *H/Ca Activity Ratios in some Ghana Soils.*—K. A. Quagraine and A. S. de Endredy (Soil Analyst), Scientific Services, Ministry of Agriculture.

The ratio $^{a}H/^{a}Ca$ was measured in a selection of Ghana soils and the results compared with amounts of exchangeable Ca (and Mg) and the degree of base saturation in the same soils. The results indicate that the ratio $^{a}H/^{a}Ca$ and its derived quantity $pK = pH-\frac{1}{2}p\,Ca$ characterise the Ca-status of the soils far more accurately. A brief account of the theory of " nutrient potentials " is given.

9. *A Brief Note on the Transition Zone of the Tain Basin, Ghana.*—E. O. Asare, Soil Survey Officer, Scientific Services, Ministry of Agriculture.

The paper discusses a soil survey of the Tain Basin in the Brong Ahafo Region with respect to the mapping of soils, land-use and vegetation types as well as assessment of the agricultural potentialities of the area. The Transition zone in question occupies an area of about 1,000 square miles which forms part of the " Middle Belt " in Ghana. The biotic factors affecting the vegetation of this area are discussed, and it is suggested that large areas of derived savannah in this area will grow back to forest when cultivation and burning are eliminated.

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CONFERENCE PHOTOGRAPH 1961

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